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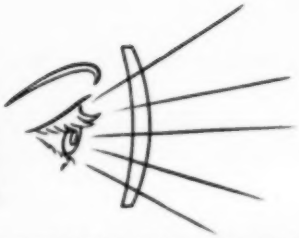

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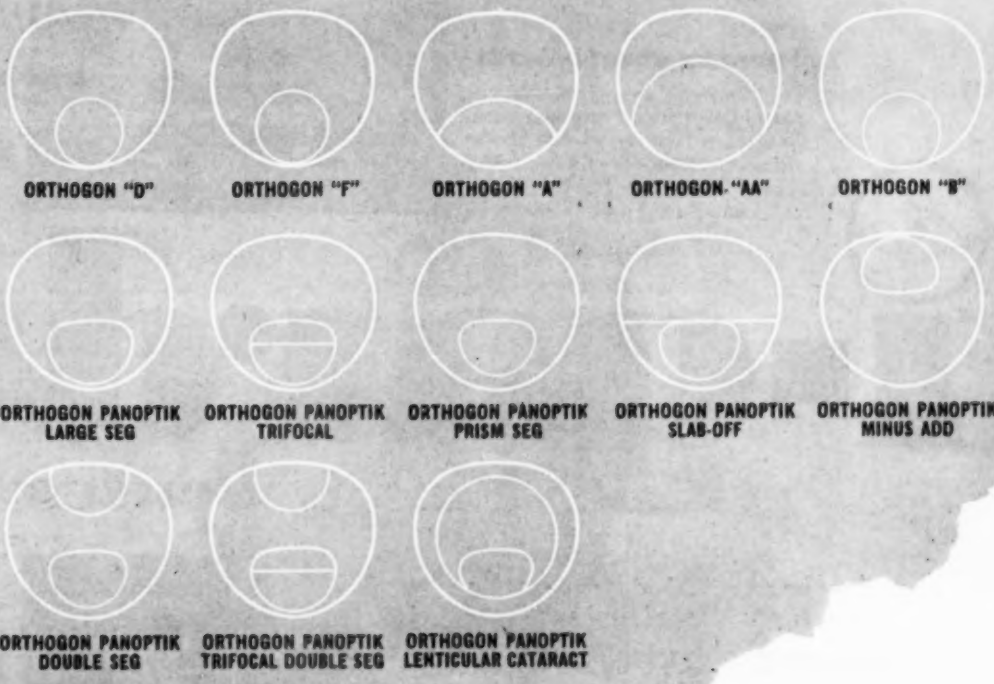

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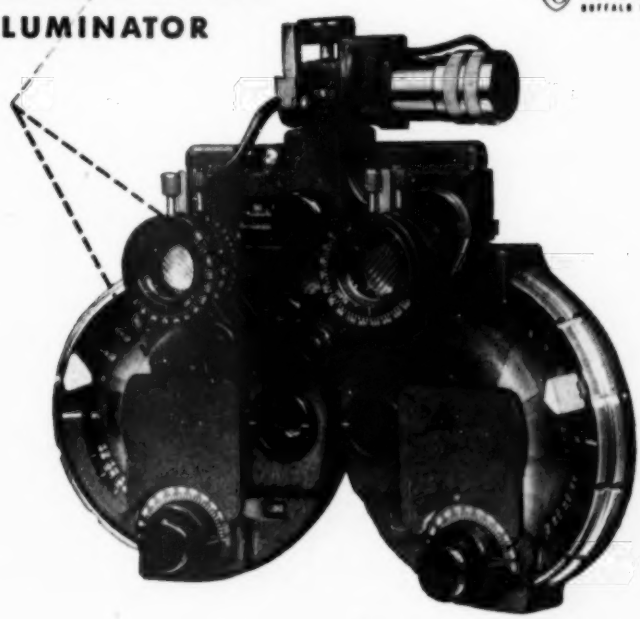

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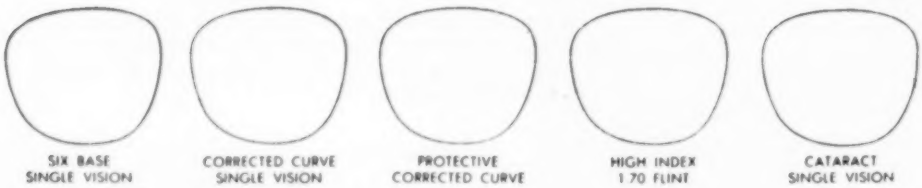

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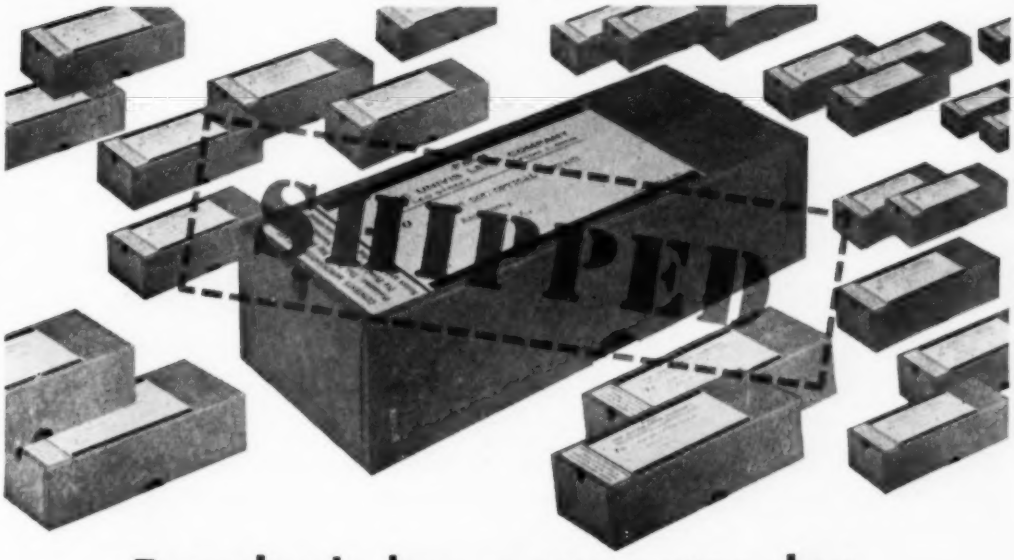

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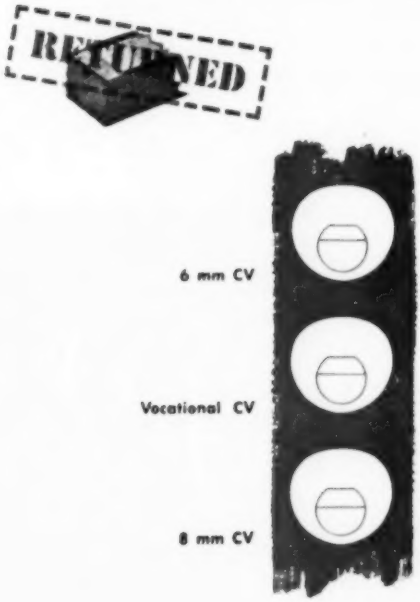

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AMERICAN JOURNAL OF OPTOMETRY
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THE ELECTRICAL RESPONSES OF THE EYE*

PART I. RESPONSES OF SINGLE PHOTORECEPTORS

David D. Michaels†
Chicago College of Optometry
Chicago, Illinois

INTRODUCTION

Historically, the electrical changes exhibited by living tissue are a relatively recent addition to scientific knowledge. The fact that such changes in electric potential are exhibited by the eye and further that these changes bear a definite relation to light stimulation was discovered by Holmgren (1866) and independently by Dewar and McKendrick (1873). Holmgren observed that when one nonpolarizable electrode is attached to the optic nerve and the other to the cornea of an excised frog eyeball, a steady current of injury flows from the cornea through the galvanometer, to the optic nerve.‡ When such a preparation is stimulated by light, Holmgren observed that the current showed an increase both at the onset and at the end of stimulation. These changes in the current he identified as the "on" and "off-effects" and he was able to demonstrate that, within limits, they are proportional to the light intensity. In order to eliminate the objection that the changes in current are the result of the activity of the iris muscle, he showed that identical results can be obtained using only the posterior half of the eyeball. In such a preparation, one electrode touches the retina while the other is attached to the optic nerve as before. Dewar and McKendrick independently arrived at these results and proved conclusively that the observed changes are the result of retinal activity.

Considerable work has been done on the electrical manifestations

*Submitted on May 10, 1953, for publication in the September, 1953, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
†Optometrist. M.S., Chairman, Department of Biologic Sciences. Fellow, American Academy of Optometry.
Part II, Optic Nerve Responses of Complex Eyes, will appear in the October issue.
‡Credit for the discovery of this "resting potential" goes to DuBois-Reymond in 1849.

since that time particularly by Waller (1900); Gotch (1903); Brucke and Garten (1907); Einthoven and Jolly (1908); Chaffee, Bovie and Hampson (1923);** Adrian and Matthews (1927-28); Graham (1934);** Hartline (1940);** Bernhard (1940)** and Granit (1947.** Of these, the communications marked by a double asterisk (**) contain excellent reviews and summaries. The reader is referred to the bibliography as well as the references of the above papers for a more comprehensive review of this most fascinating and most modern of areas in visual physiology. In this paper, we will devote our attention to only the most comprehensive studies and consider the problems which seem (at least to this writer) the most pressing.

The validity of the results to be discussed have gradually improved with the development of instruments and techniques necessary for recording such minute amounts of current. Thus, the cathode ray oscilloscope has come to replace the string galvanometer and capillary electrometer of the early workers. Similarly, the development of techniques for recording action potentials from single optic nerve fibers by means of microdissection and microelectrodes has added materially to our knowledge of the intricacies of the visual process. As Granit (1947), P. XVIII, points out:

"Of the methods known to us at the present time, the electrophysiological one alone has enough sensitivity, speed, and precision to be really useful in the analysis of the fast retinal processes that mediate our sensations of light. Chemical methods have, so far, yielded very little information, photochemical work on the light-sensitive substances of the retina somewhat more, but the results have been concerned with the static rather than the dynamic factors in the receptive mechanism. In order to learn whether a given photosensitive substance, extracted from the eye, has any sensory significance, its reaction to light must be shown to bear some simple relation to the discharge of impulses in the optic nerve. Many substances found in an eye may be photosensitive, but this property, as such, does not necessarily imply mediation of sensations of light. In the end therefore, we have to fall back on recording the electrical activity of the light-sensitive end-organ or the impulses set up in its nerve to discover whether the reactions of an extracted substance were actually represented in the message carried to the brain. In man, sensations, and in animals, reflex reactions may, in this particular case, provide us with a substitute, but the electrophysiological method reaches farther. By microdissection the electrical activity of single or a limited number of sensory units can be isolated and recorded and the complex message, integrated by the brain as colour, or pattern can be split up into the letters, words, and sentences of its language."

Even those who do not share Granit's enthusiasm must appreciate the potential of this statement. To modify Pascal's wager, if we agree with men like Granit and Adrian and they are wrong, we have lost nothing. But if they are right, we will have gained everything, not only in understanding the visual process but, in the long run, why man behaves the way he does.†

†See in particular Adrian (1947) "The Physical Background of Perception" Oxford.

PART I. RESPONSES FROM SINGLE PHOTOCEPTORS

With present techniques it is as yet impossible to record the electrical activity of single photoreceptors from complex retinas, i.e. retinas containing internuncial neurons. The best we can do is obtain records from single optic nerve fibers (e.g. ganglion cells). In order to study the photoreceptor activity it is necessary therefore to use an eye in which the sense cell terminal *is* the optic nerve fiber. Such an eye is that of the invertebrate horseshoe crab *Limulus Polyphemus*. In this animal, the eye is made up of a number of individual ommatidia each of which corresponds to one facet. Each ommatidium contains some 14 to 16 light sensitive cells. The interesting property of this eye, the one which makes it an ideal preparation, is that each photosensitive cell is directly connected to a single nerve fiber without any intervening synapses. Further, as if this animal were expressly designed for study by neurophysiologists, the nerve contains little connective tissue and can easily be separated into bundles of relatively few fibers or, with more care, into single, individual nerve fibers.

Hartline and Graham (1932) used such a preparation in an attempt to detemine the characteristics of a single receptor of the eye. By a technique of microdissection a single optic nerve fiber was slung over silk electrodes and oscillograms of the potential changes were obtained. The stimulus was controlled both with respect to duration and intensity. The eye chamber could be positioned with a vernier micro-manipulator such that the position of the eye was controlled to within 0.01 mm. The recording instrument was a Moving-Reed oscillograph activated by an appropriate amplifier such that three microvolts would produce a deflection of one mm. of the electron beam.

The typical discharge of a single fiber begins after a short latent period (about 1/5 second) with a burst of impulses of high frequency. Each spike is of the same size (Adrian, 1928). After the initial burst there may be a "silent period" of no spikes if the intensity is high. The initial burst is then replaced by a discharge which is slower and more regular and whose frequency is roughly governed by the intensity. (Figure 1.) This train of impulses continues as long as the eye is stimulated, and dies out, after a latent period, when the light is shut off. The evidence on which Hartline and Graham base their belief that these results are indeed the response of a single element is threefold. First, the discharge is regular and uniform. Second, splitting the fiber which yields such a regular discharge gives one part which is *inactive* and finally, measuring the actual area of stimulation which gave results for one fiber

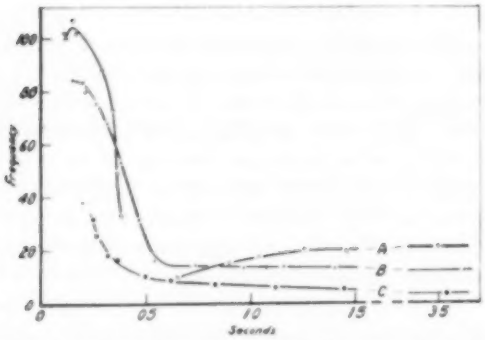

Fig. 1. Frequency of impulses (number per second) versus time after the onset of illumination.
Curve A: intensity 0.1
Curve B: intensity 0.001
Curve C: intensity 0.0001
Points give the average frequency of four successive impulses. After Hartline, 1934.

under 40X magnification reveals this to be one ommatidium which presumably contains the single, active photoreceptor.

When the intensity of the light is increased, the initial maximum frequency as well as the rate of the subsequent steady discharge is increased. Each spike, however, remains of the same height (about 0.6 mv) obeying the all or none law.* When the intensity is decreased, there is a decrease in frequency, the discharge (at low I's) tends to become irregular and the latent period increases. These results are in accord with those obtained from other sense organs (Adrian and Zotterman, 1926; Bronk, 1929; Matthews, 1931). Figure 2 presents the oscillograph records of the action potentials of single optic nerve fibers obtained at four intensities.

When the frequency of discharge is plotted against time, a curve is obtained which drops rapidly within the first ½ to 1 second or so and then smoothes off to a steady horizontal line (about 25/second for average intensities) after that. This recovery process was investigated by Riggs (1940). The course of the recovery process was ascertained by stimulating the receptor with a test flash at random intervals during

*This law is often misunderstood. It states that the cell will respond to its maximum *capacity* at that particular instant and not that it always responds the same way. If the electrode is attached differently or if the cell is inhibited by adjacent activity, the spike will not be of the same size and, of course, this does not imply that the all or none law is being disobeyed. It has been suggested (Alpern-personal communication) that a desirable statement of the all or none law in concise form is that—it is impossible to grade the amplitude of the response by increasing the magnitude of the stimulus.

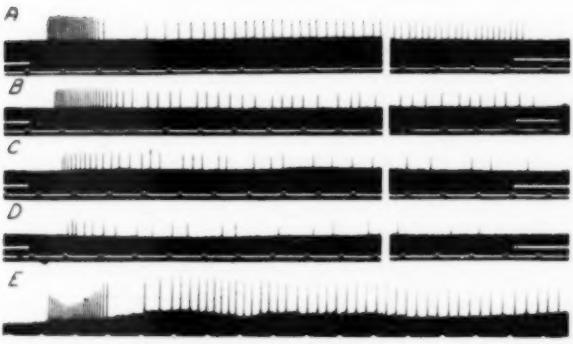

Fig. 2. Action potentials from a single optic-nerve fiber.
A to D—intensity of stimulation respectively 0.1, 0.01, 0.001, and 0.0001 in arbitrary units (1 unit = 630,000 meter candles at the eye). The gap in each record represents an interval of 2.8, 1.4, 4.5, and 3.3 seconds respectively.
E—from another preparation, showing effect of high frequency of response on height of individual action potentials. (From *J. Cell. & Comp. Physiol.*)

the discharge which follows long continued illumination by an adapting light. The nature of the response to the test flash now serves as a quantitative indicator of the recovery process. This is analogous to the conventional neurophysiologic technique of conditioning shock-test shock on which the excitability curve of nerve is based. Riggs found the recovery process to have a regular and measurable course. The latency of the response to the test flash varies with the time interval (after the adapting stimulus) and the intensity of the flash added to the existing illumination. When the reciprocals of the latent periods are plotted against log I of the flash a roughly linear relationship is obtained (Riggs, 1940).

Returning now to the experiment of Hartline and Graham (1932), when the initial frequency of discharge for example was plotted against the logarithm of the intensity, a linear relation obtains which is interpreted as approximating the Weber-Fechner law. (Figure 3.) This law states that the sensation varies as the log of the intensity of the stimulation and, since the visual sensation which Limulus experiences is presumed to be a function of the frequency of the nerve messages traveling up its optic nerve, this interpretation seems a reasonable one. The range of intensities over which a single receptor can respond with varying frequencies may range from 1 to one million.

If it is correct to assume that the nerve fiber discharge reflects the photochemical changes occuring within the sense cell to which it is directly attached, then we should expect the frequency of the discharge to

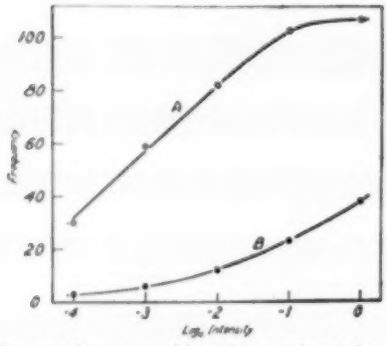

Fig. 3. The relation between frequency of impulses and logarithm of the light intensity.
Curve A—frequency of the initial maximal discharge.
Curve B—frequency of discharge 3.5 seconds after onset of illumination.
Data from Fig. 1 plus other records of the same experiment. (From *J. Cell. & Comp. Physiol.*)

be a function of the absorption characteristics of the photochemical substance (erythropsin) which that cell contains. This hypothesis was tested by Graham and Hartline (1935). They subjected the eye of Limulus to stimulations of various wave lengths of approximately equal energy. They found that the response to green light (530 mμ) is stronger than the response to red (640 mμ) or violet (440 mμ). Thus for 530 mμ the latent period was shorter, the initial frequency higher and, for constant flash durations, a greater number of impulses were discharged. When the response criterion is plotted against wave length, a well defined visibility curve is obtained which has as its maximum

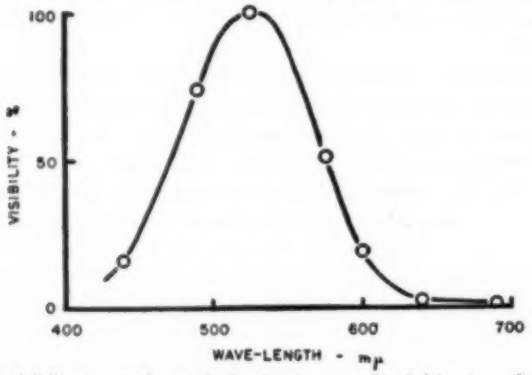

Fig. 4. The visibility curve for a single visual sense cell of *Limulus*. Ordinate represents the reciprocals of the relative intensity necessary to produce a specified burst of impulses. After Hartline, 1941.

530 mμ. (Figure 4.) Since the records are from a single fiber, no Purkinje shift is observed. Hartline and Graham went further and tried to determine whether there exist single fibers which gave different responses. They did find that fibers coming from differently located ommatidia showed visibility curves which differ significantly from each other (see e.g. Figure 5) in a large percentage of cases (ca. 50%).

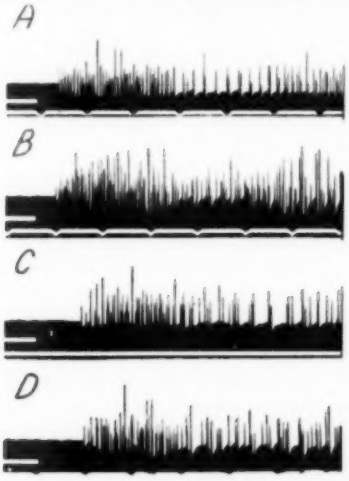

Fig. 5. Oscillographic records of action potentials in optic nerve in response to illumination of the eye of *Limulus*.
A—record obtained from an illuminated area comprising 2 ommatidia.
B—record from an area containing 33 ommatidia.
Records A and B at an illumination of 1 arbitrary unit (4500 meter candles at the surface of the eye).
C—record from an area containing 10 ommatidia.
D—record from an area containing 121 ommatidia.
Records C and D at an illumination of 0.01 arbitrary unit.
Upward deflection indicates increasing negativity of lead next eye. Lower white line indicates time in fifths of seconds; tuning-fork line superimposed on this gives time in hundredths of seconds. Line above time record signals the onset and continuation of illumination. (From *J. Cell & Comp. Physiol.*)

They consider this as evidence for a peripheral mechanism of color vision. This means that either different sense cells contain different photosensitive substances or there was a variation in the technique such as the attachments of the electrodes. In any single fiber, however, the intensities of the less effective wave lengths may be adjusted so that the three colors agree with each other impulse for impulse. (Table I.) This means that there is no specific effect of wave length other than one of brightness (and therefore photochemical absorption) in a single receptor element—at least for the Limulus eye.

TABLE I

Exposure Sec.	Central Wavelength $m\mu$	Log Relative Energy $\log_{10} I$	Latent Period Sec.	Initial Frequency /Sec.	Maximum Frequency /Sec.	No. of Impulses First Burst	Frequency at 3 Sec. /Sec.	Time of 50 Impulses Sec.
0.04	640	1.64	0.329	39	39	7		
	530	2.00	0.325	39	39	7		
	440	2.64	0.356	38	38	7		
	640	1.64	0.121	78	98	29		
	530	0.00	0.112	78	97	30		
	440	0.64	0.123	79	96	29		
∞	640	1.64	0.246	44	65		14.7	2.08
	530	2.00	0.238	47	64		14.7	2.42
	440	2.64	0.251	43	63		14.6	2.52

After Graham and Hartline, 1935

The hypothesis that the electrical responses of the sense cell axon reflect the photochemical changes within the cell, has other consequences. It can be shown that within limitations, duration and intensity may be effectively interchanged to produce a constant effect. Hartline (1934) investigated these inter-relationships of time and intensity on the single element of Limulus. He showed that, to produce a given constant response in terms of a criterion of specific frequency (e.g. 40/second), the expected reciprocal relation held good. For brief durations (up to 0.1 second) the effect of changing the time is equivalent to changing the intensity. If, instead of initial frequency, the total number of impulses produced by the stimulus is used as an index, the relation holds for even longer durations. This is interpreted as indicating that the photosensory mechanism has a simple photochemical basis to which the Bunsen-Roscoe law may be applied. The reciprocity relation fails, however, if the duration of the flash is longer than the time of appearance of the response criterion. At a certain critical duration, the reciprocity relation is superseded by the condition I = constant. Since this critical duration is appreciably shorter than the time of appearance of the impulses, it is concluded that the impulses are determined within the sense cell prior to their appearance under the electrodes. These relations are indicated in Figure 6.

Riggs and Graham (1940) continued the investigation concerning the adaptation process in a single photorecepter unit. In the vertebrate eye the frequency of the discharge in a single fiber is usually an unsatisfactory index of the photochemical mechanism of adaptation because of the influence of intervening neurons (Granit, 1947). In the Limulus eye however, where conditions are much simpler, the frequency of the discharge should reflect the adaptation process. Riggs and Graham

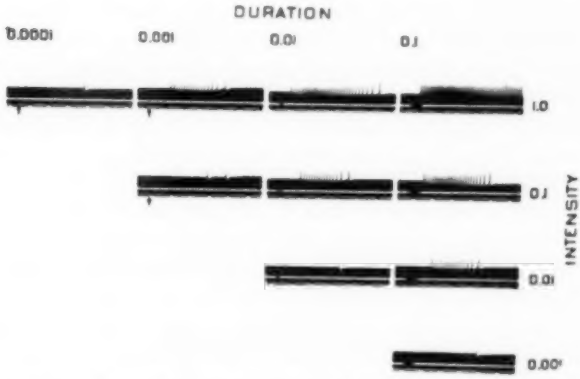

Fig. 6. Oscillograph records of action potentials from single optic nerve fibers of *Limulus*, in response to illumination of the eye by flashes of light of various intensities and durations. 1 arbitrary unit of intensity = 3.0×10^6 meter candles. After Hartline, 1934.

investigated the light adaptation process by adding flashes of light (Δ I) at various times after the onset of response to a constant adapting light and observed the increase in impulse frequency which results. They found that if the adapting intensity is high, the initial burst of impulses is followed by a silent period. With lower intensities this silent period is absent. The silent period is responsible for the discontinuity observed in the curves when frequency of response is plotted against time for high intensity values. Now when the Δ I flash is added, the frequency of response increases during the first up to 80 seconds of light adaptation and then slowly declines during the remainder of the process.

An exception to this rule occurs with high intensities. The sensitivity was measured by using the reciprocal of the increment of intensity which must be added to produce a constant increase in the frequency of the response (i.e. Δf). They chose $\Delta f = 30$. Riggs and Graham found that in the first 20 to 80 seconds there is an increase rather than a decrease in sensitivity. This means that when the data of $1/\Delta I$ vs. log time in the light is plotted, one obtains a bell shaped curve. The possibility is suggested that processes associated with the initial burst and the silent period may mask or suppress the responses to flashes occurring early in the exposure period. However, the initial rise in sensitivity is observed even with low adapting intensities which gives neither burst nor silent period. Finally, Riggs and Graham point out that the silent period is entirely over within 10 seconds whereas the peak of sensitivity does not occur until 10 to 70 seconds later. The

significance of this initial rise in sensitivity remains unclear. Granit (1947) suggests that it is more probably a nervous rather than a photochemical mechanism which is involved. He cites as evidence for this view the experiment of Riggs (1940) in which the initial receptor mechanism was effectively excluded. Some sort of a supernormal period might well be responsible for this phenomenon. On the other hand it may be an expression of the rhythmic activity of the fiber.

The dark adaptation process in a single photoreceptor element of Limulus has been investigated by Hartline (1930), Hartline and McDonald (1941) and more recently Hartline and McDonald (1947). After an initial exposure to light of known intensity, the increase in sensitivity in the subsequent dark period is measured by recording the number of impulses resulting from a test flash of constant intensity presented at varying times after the initial exposure. As a typical result, (Figure 7), it was found that the number of impulses resulting from a test flash presented 30 seconds after the initial exposure was four; after

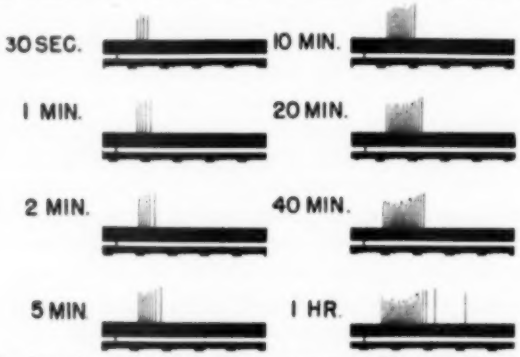

Fig. 7. Dark adaptation of a single visual receptor of *Limulus*. Oscillograms of the amplified action potentials of a single fiber showing impulse frequency to a test flash of constant intensity applied in the dark at various times after light adaptation. Time marks = ½ second. Flash duration = 0.008 seconds. After Hartline and McDonald, 1947.

five minutes of dark adaptation, the same flash resulted in nine impulses and after one hour in the dark, the number of impulses resulting from the test flash had increased to a maximum of about twenty-six (Hartline and McDonald, 1947). When the data is plotted as number of impulses vs. time in the dark, a curve is obtained which rises rapidly at the beginning and then levels off after about 10 minutes or so. This curve resembles the theoretical curve derived from photochemical theory as well as those obtained from clinical data. (Figure 8.) When the intensity or the time of exposure of the adapting light is increased, there

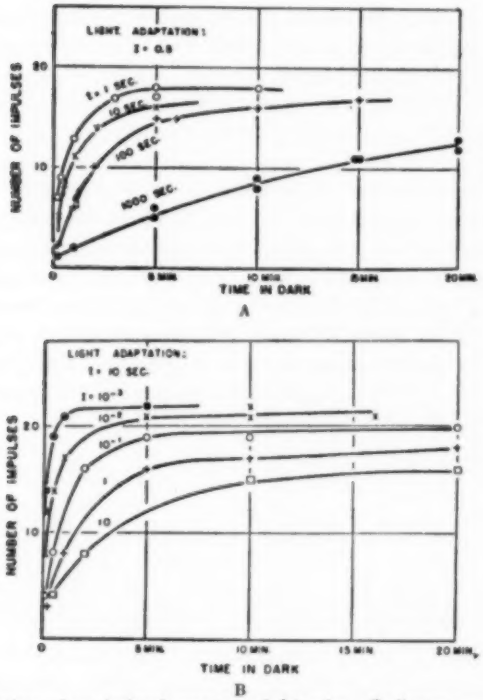

Fig. 8. Adaptation of an isolated receptor of *Limulus*. Ordinates represent frequency of nerve impulses to a brief stimulus of constant intensity and duration. Abscissas represent the adaptation time. Curves A = influence of duration of pre-adaptation. Curves B = influence of intensity of pre-adaptation. After Hartline and McDonald, 1947.

is a corresponding greater initial loss of sensitivity and a longer recovery time.

In reviewing these results Adler (1950), P. 485, concludes:

"It would seem that the fundamental properties of the simple photoreceptor cells of Limulus are sufficient to account for all the changes seen in more complex retinas during light and dark adaptation, and that it is not necessary to postulate activities other than those which reside in such simple units."

On the other hand, as Hartline and McDonald caution, these studies do not exclude the possibility of additional effects in the vertebrate eye, nor can a comparison between the receptor element of Limulus and the vertebrate photoreceptors be made without reservation. Nevertheless, the studies so far described provide powerful support for a photochemical theory of vision. Such a theory, it will be recalled, was also originally derived from simple types of photoreceptors. The remarkable agreement

of the photochemical and electrical results with respect to the Bunsen-Roscoe law, visibility, adaptation and the Weber-Fechner function, though they may be spurious, cannot be ignored. The evidence is in fact too good, for even if we accept the reservations of Hartline and McDonald (above) we may begin to look with a critical eye upon the role played by the intervening neurons and the more complex synaptic chains found in the eyes of vertebrates. If the results obtained on Limulus have any significance at all, we must conclude that vision, even of a rather complex form, is possible without the more detailed arrangement of histologic elements found higher up in the phylogenetic series. In order to determine the effects of such arrangements we will have to examine the results obtained from the nerve fibers of more complex eyes. As a preliminary guess, we may expect these effects to be on the order of modifications and additions rather than substitutions of the results so far obtained from Limulus studies.*

*Part II, Optic Nerve Responses of Complex Eyes, will appear in the October issue.

ANNOUNCEMENT

MOTE JOINS INTERPROFESSIONAL COMMITTEE

Dr. James F. Wahl, President of the American Optometric Association has announced the appointment of Dr. Herbert G. Mote, Columbus, Ohio, to the Committee on Interprofessional Relations of the A.O.A. and as one of the four optometric members of the National Interprofessional Committee on Eye Care. Dr. Mote is a faculty member of the School of Optometry, The Ohio State University. He takes the place of Dr. Glenn Moore, Chicago, who retired from the committee with regret. Dr. H. Ward Ewalt, Pittsburgh, will serve as Chairman of the Committee. The other members being Dr. William C. Ezell, Spartanburg, South Carolina, and Dr. Carel C. Koch, Minneapolis.

THE LUNEBURG DISTORTION OF VIETH-MUELLER CIRCLES*

L. Ivan Epstein†
Scientific Bureau, Bausch & Lomb Optical Company
Rochester, New York

In a recent publication[1] I pointed out the contradiction between an experiment quoted by R. K. Luneburg[2] and a similar (but not identical) experiment by K. N. Ogle[3] and W. Herzau. I also suggested an explanation for the discrepancy. I would like to explain this matter in more detail.

Luneburg made the following statement: "We arrange a number of equidistant light points on a Vieth-Mueller circle. . . . These points are seen in the visual space as equidistant points on a circle about the center of observation." We are not told who performed the experiment. At first sight, this result strikes one as incredible, unlike the rest of Luneburg's theory. All else that Luneburg claims is in agreement with everyday experience. For instance, the sun and moon appear to be only a few miles away and to be only about the size of a pumpkin. Actually, a pumpkin even one mile away would appear much smaller than the moon. Or, if the average person is asked to draw a circle of the same apparent size as the moon, he will make it of about the same size as a 5-cent piece, to be viewed at normal reading distance. Actually, a pea would be much too large. In view of these contradictions in everyday experience, Luneburg's use of non-euclidean geometry is not surprising.

On the other hand, Luneburg's claim that a physical Vieth-Mueller circle is so totally unlike its image in the visual space, is contrary to everyday experience. This in itself does not refute Luneburg's claim of such a dissimilarity, unless a controlled experiment leads to the same conclusion. Such an experiment was performed by K. N. Ogle and W. Herzau.

Ogle and Herzau fixed the observer's head in position, placed the horopter apparatus in a position requiring asymmetric convergence at near (Figure 1), and instructed the subject to arrange the horopter rods in a plane which would appear normal to the mean line of sight. This plane is not an apparent frontoparallel plane, but an apparent normal

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†M.S.

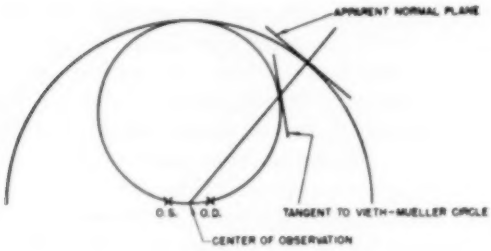

Fig. 1

plane, and this should appear to be tangent to a circle about the center of observation. According to Luneburg, one would expect the observer to set the rods along a plane tangent to a Vieth-Mueller circle. However, the Ogle-Herzau experiment did not confirm this. Instead, the apparent normal plane was much closer to a true normal plane than to a tangent to a Vieth-Mueller circle.

Two questions now arise: (1) What is the cause of the discrepancy between the experimental results obtained with luminous dots in the one case and with horopter rods in the other? (2) Does the Ogle-Herzau experiment prove Luneburg's theory wrong, or how can this theory be modified to take the Ogle-Herzau result into account? I can do no more than offer speculations on these questions. Further experimental research will be needed to put any conjecture to the test; and Dr. Ogle[4] is right in urging a cautious attitude towards any such speculations.

In order to answer question (1), let us examine more closely the process of spatial localization in asymmetrical fixation. Let a rectangle be placed in an off-center position. Let it be oriented so that it lies in an apparent normal plane, with two of its sides horizontal, the other two vertical. To take a specific example, let the object be placed right of center. Figure 2 shows schematically a stereogram of this object. The differences in size between the two images have been exaggerated for purposes of illustration. Since the rectangle is closer to the right eye than to the left eye, its image on the right retina will appear both wider and higher than its image on the left retina. If horizontal disparity were

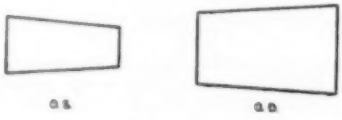

Fig. 2

the only factor involved in spatial localization, this rectangle would appear rotated into such a position that its right side would appear more distant than its left side. Of course, the vertical edges would be seen without geometric horizontal disparity only if they fell on the same Vieth-Mueller circle, and this, according to Luneburg, is the condition for making the rectangle coincide with an apparent normal plane. Ogle[5] cites evidence to the effect that the proprioceptive sense of the extraocular muscles is too weak to play a significant part in space perception, except under very extreme conditions. He has found that vertical disparity plays a part in space perception and has postulated that this is the mechanism which prevents the observer from seeing space with a lateral distortion. His experiments on the induced size effect bear this out.

A horizontal row of luminous dots, such as was used in the experiments described by Luneburg, cannot present any vertical disparity. At first sight, this appears to explain the distortion of the Vieth-Mueller circles reported by Luneburg. But why was not the same distortion observed by Ogle and Herzau? Was vertical disparity somehow involved in their experiment? Did the rectangular frame through which the horopter rods were viewed furnish the necessary clues of vertical disparity? I agree with Dr. Ogle that the answer may well be *no*. For such an aperture was also used in the experiments on the induced size effect. And yet this latter effect was not observed unless beads were slipped over the rods. Even then, two beads slipped over the middle rod alone produced only a slight effect. If vertical disparity is not the explanation of the Ogle-Herzau experiment *vs.* the Luneburg experiment, then we have here an unsolved problem.

In an attempt to discover the effect of vertical disparity on the alley experiments, I suggested that these experiments be performed with vertical pairs of lights instead of single lights lying in a horizontal plane. I agree with Dr. Ogle that the outcome of such an experiment is doubtful. For if the spacing between the two lights is the same in all pairs, perspective clues will not be eliminated. On the other hand, if the vertical spacings are so chosen that all pairs subtend the same angle at the center of observation, an inhibiting factor due to the spurious perspective may make itself felt. Dr. Ogle observed such an effect[6] in connection with his experiments on the induced size effect, if two beads were slipped over each horopter rod and aligned on two horizontal levels.

In the recent repetition of the alley experiments by L. H. Hardy and his group[7] the dots of light were placed in a horizontal plane some-

what below the level of the observer's eyes. The manner in which this complicates the effect under investigation is best explained as follows: Suppose for the moment that the experiment were performed with pairs of lights, the upper as much above the level of the observer's eyes as the lower is below this level. Figure 3 shows schematically the

Fig. 3

appearance the apparatus as seen by the two eyes. Letters R denote the positions of the dots as seen by the right eye, and L indicates the corresponding positions as seen by the left eye. In this drawing, all disparities have been exaggerated for purposes of illustration. Only a few of the alley lights are shown. The vertical line at the center lies in the plane of symmetry of the observer's face.

Now suppose that the upper light of each pair is turned off. The remaining lights then form the type of configuration used in L. H. Hardy's experiments. In this case, it will be seen that, throughout, the lights right of center will appear to lie too low as seen by the right eye, whereas those left of center appear too high to the right eye. Hence it is to be anticipated that the eyes will perform a cyclotorsional movement to eliminate the resulting vertical disparity. This statement applies to this type of configuration only, and not in general. Since the sides of the alley are curved, elimination of vertical disparity by a cyclotorsional movement may be incomplete. The result is a highly complicated situation, and it is questionable whether results obtained under such conditions can be taken at face value.

The opinions expressed in this paper are offered with the intention of stimulating further discussion. The questions raised probably cannot be answered without further experimental work.

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SEEING AND READING*

Donald L. Cleland†
The Reading Laboratory, University of Pittsburgh
Pittsburgh, Pennsylvania

If you were to ask anyone for a definition of reading, the most common answer would be: "Reading is the interpretation of the printed page." I am not sure all would express it in these exact words, but I feel confident that definitions given would connote the same general meaning. The implication is that reading is largely a *central mental* process. The stimuli or impressions which give rise to these interpretations are printed words or symbols, and these impressions are secured through the visual mechanisms. A moment's thought, then, makes us realize the tremendous importance of the eyes during the reading process. And I say *reading process* advisedly, as all students know that reading is not a subject; does not have subject matter of its own, but that it is a process, a tool, or a skill that is used in 80 to 90 per cent of all learning activities in the public schools of today.

As is well known, the eyes in reading do not move across the printed line in a smooth continuous movement. They move in a series of rapid stop-and-go movements. At the beginning of the line they rest for an instant, move to the right a short distance, stay there a moment, move quickly to the next place, and rest again. This process continues until the end of the line is reached, and then the eyes swing back to the beginning of the next line. These jerky movements of the eyes during the reading process were discovered by Javal, of the University of Paris, and were called "saccades." Today, we call these movements, "saccadic movements." Since this discovery, much research has been done on eye movements, perception, visual fatigue, blinking, etc.

Reading and seeing are both central processes. The image that is focused on the retina is transferred to the brain by the optic nerve. It remains just a signal until a person's background of information and experiences gives it meaning.

Much of what we know about the psychology of reading has been obtained through careful research of the movements of the eyes during the reading process. My purpose today is to recall to you some of

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†Ph.D. Director of Clinic.

these researches. Time will not permit me to survey all the researches pertaining to eye movements in reading. The ones I have chosen to review for you are significant ones in my estimation.

My remarks will be divided into three parts: *First*, reviews of some of the studies pertaining to the actual reading process; *second*, a review of studies of visual factors which may or may not differentiate a good reader from a poor reader; and *last*, a review of studies on visual fatigue as a result of prolonged and continuous reading.

One of the oldest concepts of learning in psychology is called *associative learning*. Learning to read is primarily a process of associative learning. To use modern nomenclature, associative learning would be called *conditioning*. The association in learning to read is that between the symbol and the sound it represents. In other words, as the child sees the three symbols *c-a-t*, he immediately associates with the symbols the sound *cat;* and he also associates with both the symbols and the sound a furry animal with a long furry tail. To use the modern nomenclature, the child is conditioned so that when he sees the stimulus CAT he says cat and he immediately has a visual image of the furry, small animal that says "meow" and purrs when it is stroked. In beginning reading, the child must associate the sound and the meaning with each stimuli or symbol that he sees on the printed page. In other words, each child must perceive each symbol on the printed line. When the stimulus THANKSGIVING is shown to the child, does he see each letter in the word? Or are there certain cues that he uses to identify the word or symbol? This brings us to word perception. Let us examine some of the research relative to word perception.

During the last war, a study was made to determine what criteria were used in the selection of radar operators. A particular sailor was asked what his civilian occupation was just prior to enlistment. He replied that he had been a Rodeo performer out west. When questioned further about the discrepancy between his civilian occupation and his naval assignment, the only explanation that he could offer was that when going over his records, the classification officer must have misread Rodeo as Radio, and so had marked him as a likely prospect for radar training. Whether this story is true or not, it poses the question, "What are the visual cues involved in word perception?"

The visual cues which are involved in word perception have been investigated by the use of a tachistoscope. A tachistoscope is well suited for this purpose, as in reading the eyes themselves function something like a tachistoscope. As described before, during the reading process the eyes do not move continuously across the printed line, but move in a

stop-and-go fashion. During the stop, or fixation as it is called, the eyes perceive the printed symbol. This stop or fixation lasts for about 250 milliseconds for the average adult reader.[1] A tachistoscope permits much the same type of exposure. Words, phrases, or sentences can be exposed; the time and area of exposure is controlled by the operator. If we should examine the research in word perception by the use of the tachistoscope and should attempt to classify it as to the types of cues which aid the most in word perception, three types of cues would be found. They are: *First*, individual letters; *second*, small letter groups; and, *third*, word shape or form.

INDIVIDUAL LETTERS

According to some workers, individual letters constitute the most important cues in word perception. These letters may be called the high and low letters, or, as some have called them, the ascenders and descenders; the initial letters; and the capitals. In regards to ascenders and descenders, two experiments were conducted to determine the legibility of individual letters. In the one case, nonsense words were used, and they were exposed by a tachistoscope.[2] From the results of the experiment, the letters of the alphabet were arranged in the order of legibility. Among the first thirteen were seven ascenders and descenders. In two other experiments, an attempt was made to determine the legibility of the letters in isolation. From the results of the experiment, the letters were arranged in the order of their legibility. It is interesting to note that among the first thirteen there were nine ascenders and descenders. In another experiment, an attempt was made to find the importance of the initial and final letters as cues in word perception.[3] The first two and the last letter received the highest frequency in the number of correct recalls. Research clearly substantiates the contention that individual letters—the ascenders and descenders (letters such as l, b, y, d, h, g, p, f, j, k, i, q), the initial and final letters of a word, and the capital letters—are available as clues.

SMALL LETTER GROUPS

This group includes the double letters, such as ll, oo, ee, etc.; prefixes, especially the common ones; and, of course, the suffixes; and certain parts of words which are common, such as the root words. I am reminded of the boy who said he could always remember the word LOOK because of the two eyes in the middle looking at him.

WORD SHAPE OR FORM

This is premised on Gestalt Psychology. During the war, a system was devised to teach the rapid recognition of enemy aircraft and

sea-going vessels. For the airplanes, a plan called the "WEFT" system of plane identification was used. The "W" referred to the wings, whether monoplane or biplane, whether they had rounded or square tips, thick or thin leading edges, etc.; "E" referred to the type of engine, whether radial or in-line; "F" referred to the general outline of the fuselage, whether long and narrow or short and thick; "T" referred to the general shape of the tail. Dr. Renshaw, experimental psychologist from Ohio State University, claimed that such a system was unsound both psychologically and pedagogically. He offered a substitute which was accepted by the Armed Forces, and he instituted a training program based on the Gestalt point of view. The Gestaltist says that the whole is greater than the sum of its parts. Pictures of enemy aircraft and sea-going vessels were projected on a screen by the use of a tachistoscope. The projected pictures showed the craft in various positions as viewed by the observer. According to Dr. Renshaw this system of identification proved more accurate. Likewise, the general configuration of a word is a cue to its meaning and sound. All teachers know that a child learns the word *elephant* more quickly than he would a word such as *mean*. There is no doubt that concrete words are learned more quickly than abstract words. To test this premise, that the general configuration of the word provides a valuable clue, take a sentence in which the words are run together so that there is no letter space between the separate words and try to read it. You must consider each letter of each word. Or better yet, take a passage and make every other letter a capital letter. In this case, leave a letter space between each word. In reading it, your rate will be very slow.

I believe that the word shape or form is the most important cue in word perception. The individual letters and the small groups of letters are merely parts of the word which give the individual word its general configuration. The general configuration is of *paramount importance;* the individual letters and the small groups of letters are secondary cues of perception.

RESEARCHES PERTAINING TO THE ACTUAL READING PROCESS

As mentioned before, the eyes do not move across the printed page in a smooth, continuous manner. The actual movements are characterized by jerky movements known as saccades. The nomenclature of these movements are: fixations, inter-fixations, regressions, return sweeps, and refixations. The fixations are pauses in which the eyes view a certain portion of the print. The inter-fixation is the movement from one fixation to the next. Regressions are the backward movements of the eyes along a line of print to correct a misreading. Refixations usually

occur near the left-hand margin on the page, and the eyes will refixate whenever they have *bitten off more than they can chew*. It is a measure of the accuracy of the return sweep. Two terms which I have not mentioned yet are: *span of perception* and *span of recognition*. The span of perception is the amount of print that the eye or eyes can perceive at one look or fixation. The span of recognition is the amount of print that the eye or eyes can take in at one look and can interpret. The span of recognition is considerably smaller than the span of perception. Let us examine the word "recognition." It comes from an old French word "reconoistre" which is taken from three Latin words: *re* meaning *again*, *com* meaning *intensive*, and *gnoscere* which means *know*. Thus the word recognize means *to know again*. The span of perception is usually measured by means of a tachistoscope. The span of recognition is measured from the photographic movements of the eyes during the reading process.

The average fovea is assumed by Luckiesh and Moss to subtend a visual angle of 70 minutes.[4] The macular area is assumed to subtend an angle of approximately 12 degrees. The size of type will determine the size of the span of perception and the span of recognition. For 10 or 12 point type the span of perception is from 15 to 25 letter-spaces. The average span of recognition is 5 to 8 letter-spaces.

The question naturally arises, is there any relationship between the span perception or the span of recognition and reading skills? Is there a positive correlation between the span of perception or the span of recognition and certain visual factors? In this respect I refer to a study by Harris.[5] He studied the relationship of span of recognition in reading to ten psychological factors and nine visual factors. Information was secured from students in grades 2 to 6 inclusive and in grades 9 and 13. Significant correlations were found between span of recognition and each of the following factors in a majority of the grades tested: intelligence, rate of reading, paragraph comprehension, word meaning, span of perception, average number of regressions per line, and speed of verbal association. Very little correlation was found with visual factors. This conclusion supports the hypothesis that span of recognition is largely a psychological function. I found a significant correlation between span of perception and speed of comprehension.[6] The term *speed of comprehension* may need a word of explanation. By and of itself rate is a meaningless term. There is no indication, in many cases, of the accuracy of comprehension. The average college student reads approximately 325 words per minute. The term *speed of comprehension* is a product term. It is the product of the rate of reading and the testee's

ability to comprehend at that rate.

The duration of the fixation is an interesting item.[7] For first grade children it is about 600 to 700 milliseconds. As the child matures and increases his reading skills, the duration of the fixation decreases until he is approximately ten years old. From this age on, the duration of the fixation remains fairly constant—about 250 milliseconds. Another interesting fact is that a reader cannot voluntarily control the speed of the saccadic movement at will by looking from one object to another.[8] It is not possible for a person to "consciously drive oneself" to modify certain aspects of the reading pattern. The inference is that the speed of the inter-fixation and the return sweep is more or less constant. Dodge and Cline have measured the duration of a saccadic movement and have found that it takes from 15 to 20 milliseconds to move the eyes through an arc of one or two degrees. It takes about 40 milliseconds for a person to make the return sweep when reading newspaper print.[9] During the reading process, the fixations take up about 90 per cent of the reading time in rapid reading and about 95 per cent of the reading time in slow reading.[10] When a person is forcing himself to read faster, in reality he is either reducing the fixation time or he is making fewer fixations in reading a line, or he is doing both.

During the reading process, the eyes not only make fixations, return sweeps, regressions, and inter-fixations, but there are vergence movements manifested also. According to Carmichael and Dearborn[11] there is first a gradual upward movement of the eyes during the inter-fixation movements and the return sweep, this being indicative of divergent adjustment. The eyeballs tend normally to be relatively diverged at the end of the reading of a line of print. During the return sweep they tend to converge. At the end of a fixation pause, the eyes are slightly diverged. The inference here is that perhaps binocular co-ordination plays a more important part in the reading process than many of us think. It could be that poor binocular co-ordination is more of a contributing cause to reading retardation than we have credited it with. Surely we need more research in this area.

The rate of blinking during reading has received considerable attention during the last decade or two. Luckiesh and Moss believe that blinking rate is a function determined by the duration and severity of a visual task.[12] Their contention was derived from five experiments using from 10 to 18 subjects. The rate of blinking was observed during the first and last five minutes of an hour's reading period. The rate of blinking increased significantly during the last five minutes of the hour. In another experiment, Hoffman required 30 subjects to read con-

tinuously for four hours:[13] the rate of blinking was significantly increased after an hour's reading; and, in the remaining three hours, other significant increases were noted. Carmichael and Dearborn[14] conducted a most comprehensive experiment in which 40 subjects were required to read for six hours continuously. For one six-hour period they read from "Lorna Doone," and for another six-hour period they read from Adam Smith's "An Inquiry into the Nature and Causes of the Wealth of Nations." Another group read projected microfilm taken from the same two books. The typography and format of the projected microfilm were essentially the same as those of the books themselves. Interspersed throughout the reading of these selections were check tests which the reader was required to complete. These tests were scattered at intervals of 25 pages. Also, at the end of the six hours of reading, a comprehensive test was given on the material read. The rate of blinking was recorded on a moving tape, and samples were taken every five minutes of each half hour. Although the rate of blinking increased, there was no significant increase in the blinking rate from the initial sample period to that of the last. To quote from the authors, "The first conclusion . . . is that significant changes were not found in the various measured aspects of the eyes' behavior in reading during an experimental six-hour period."[15] It must be kept in mind, however, that the variables which were not measured were better controlled than in the aforementioned experiments. Also, it must be kept in mind that interspersed through the reading were check tests which would, in my opinion, offer opportunity for relaxation. Again, it may be that an absorbing interest in the reading material would have a tendency to reduce the number of blinks.

The size of type, type face, length of line, amount of leading, color of paper and amount of illumination have received a lot of attention among researchists. In surveying the literature, I find it very hard to come to any definite conclusion as regards these aspects of typography. There are so many variables that must be controlled if any experimental results are to be considered valid and reliable. Let us consider the complexity of any research in this respect. If you are trying to determine what is the optimal size of type, let us consider the variables which enter the picture. What size type is optimal under this illumination? What about type boldness? Does the length of line influence the findings? What about the amount of leading? Is the material for rapid reading, for skimming, or for detailed reading? What about surface or the tint of the paper? Let us consider some of the research that pertains to these factors.

Surface and tint of paper. The researches examined did not show any evidence that the surface or tint of the paper influenced appreciably the legibility or the speed of reading for short periods.[16]

Length of line. Research does not point to any definite line length; however, most agree that the shorter lines are better. It is doubtful that lines of over 90 millimeters in length are advisable.[17]

Size of type. One study indicated that children in the second grade preferred 12 point type. Another study revealed that children of all intelligence levels read 8 point type more rapidly than larger type. Another study revealed that adults favor the 12 point type.[18]

Boldness of type. Many readers believe that augmenting the boldness of type will increase its legibility. Evidence from research indicates that boldface type neither slows down nor speeds up reading rate to a significant degree.[19]

Style of type. The evidence seems to be that Garamond, Old Style, Cheltenham, and Bodoni are about equal as far as legibility is concerned. It is definitely known that American Typewriter type does slow down the rate of reading to a significant degree.[20]

Amount of leading. When speed and comprehension are combined, 4 points of leading seem to be optimal. This was based on the results of the readings of 779 second-grade school children.[21] The same experiment indicated that 5 points of leading was the best when speed was the only criteria. It is doubtful if over 2 points of leading is advisable in books for adults.

To summarize the above findings as regards type size, type face, degree of boldness, length of line, and amount of leading, research evidence seems to point to the following: Old Style, Cheltenham, Bodoni, Garamond printed in 10 to 12 point type with up to two points of leading and with medium boldness will not produce any visual discomforts for prolonged reading. It is interesting to note that Carmichael and Dearborn's book, "Reading and Visual Fatigue," in which they describe their very comprehensive experiment, is printed in Garamond, 11 point type, medium boldness, with 2 points of leading.

VISUAL FACTORS THAT MAY OR MAY NOT DIFFERENTIATE GOOD READERS FROM POOR READERS

Some writers maintain that visual disturbances are largely responsible for reading disabilities. Other writers take the opposite view and maintain that there is no relationship between the two. Some writers take a milder attitude and state that poor reading and visual difficulties may have a common cause. It is foolish to argue that visual inefficiency will not affect the reading process. The real issue seems to be one of

degree as regards reading disability. And, then, on the other hand, there is no universal agreement as to what reading disability is. All writers in the field of reading will agree that in individual diagnosis certain visual factors should be checked to ascertain if they are contributing factors to reading disability. If a child cannot read with a tolerant degree of ocular comfort and efficiency, he will avoid a reading situation whenever he can. This one thing we know—and I refer to those who are primarily interested in reading disability cases—that the efficient reader reads widely, that he enjoys reading, and that he avails himself of every opportunity to read. And because he reads widely, he has a wealth of information from which to draw to make his reading meaningful. It is not only what he gets *from* the printed page, but also what he takes *to* the printed page that makes for real enjoyment in reading. Let us consider some of the visual factors that may contribute to reading retardation.

Visual acuity. Fendrick studied children in Grades II and III who manifested reading disability.[22] A modified form of the Jaeger chart (Near Point) was used. He concluded that a statistically significant difference was isolated favoring the good reader. Eames studied 114 reading disability cases with an unselected group and found no significant difference between the good and the poor readers.[23] Farris studied 1,685 pupils in the seventh grade.[24] He concluded that the data secured did not support the hypothesis that children with defective visual acuity were always handicapped in learning to read. Stromberg studied for slow and fast reading, 71 pairs of university students whose intelligence was above average. He concluded that speed of reading could not be associated with visual acuity.[25] I examined 147 college freshmen and sophomores who were divided into good readers and poor readers.[26] No significant difference was found which would differentiate the good readers from the poor readers. In fact, 81 per cent of the poor readers had 20/20 vision, and only 76 per cent of the good readers had 20/20 vision. In all this evidence, and in other evidences I reviewed, there is no indication that visual acuity differentiates the good reader from the poor reader (far-point). The evidence mentioned, however, is based on gross measures. In individual diagnosis, visual acuity should be considered, especially at the near-point.

Hyperopia or far-sightedness. Cole, in examining reading disability cases, found that 60 per cent manifested evidence of far-sightedness.[27] Eames examined 100 reading cases and found that approximately 43 per cent of them showed evidence of far-sightedness.[28] Farris, in examining 384 cases of far-sightedness, found a high incidence of reading

retardation.[29] At the college level, Blake and Dearborn found a high percentage of students of low scholastic standing to be far-sighted.[30] This evidence and other evidence which I reviewed would indicate that there is a high incidence of far-sightedness among retarded readers. In fact, far-sightedness would appear to be the greatest differentiating visual factor in separating the good readers from the poor readers.

Myopia or near-sightedness. Eames found that myopia occurred more frequently among good readers than among poor readers. He thought that myopia might be favorable toward reading.[31] In fact, one writer stated that myopia is more prevalent among the highly educated, but that it is found in all classes.[32] Farris stated that myopia and myopic astigmatism were both associated with more than normal progress in reading.[33] Taylor, in examing 387 normal readers, found that 52 per cent were classified as myopic. Only 28 per cent of the 100 reading disability cases were classified as myopic.[34] The above would indicate that myopia may be an asset in the reading process. In this respect, it differentiates the good readers from the poor readers.

Astigmatism. Dr. Betts, Director of the Reading Clinic at Temple University, reported that up to 1934, 90 per cent of the poor readers had astigmatism beyond that which is considered tolerable.[35] Eames found less astigmatism among the disability reading cases.[36] Among the non-readers he found severe cases of astigmatism. The studies made by Swanson and Tiffin,[37] Stromberg,[38] Witty and Kopel[39] show that astigmatism was not a differentiating factor between good and poor readers. It would appear from this evidence and other evidence that I have reviewed that, in gross measures, astigmatism did not differentiate good readers from poor readers. However, in severe cases of astigmatism it was found to be closely allied with reading disability.

Binocular Co-ordination. Dr. Betts has stated that, "If we were a one-eyed race, our reading difficulties from the point of vision would be fewer."[40] Farris, who concluded from his matched pairs of reading cases that pupils whose visual perception was monocular made better progress in reading than those who lacked correct co-ordination of the two eyes.[41] I found no significant difference between the good readers and the poor readers in vertical or lateral imbalance as determined by the Betts Visual Sensation and Perception Tests. However, among those who ranked below the 25th percentile were found several cases of binocular incoordination.[42] Good, after studying 30 experimental cases and an equal number of control cases, came to this conclusion: "One is forced to conclude from the scope of this research that adduction and abduction weaknesses definitely accompany difficulty in learning to read."[43]

Fendrick, in his study, claimed that muscle imbalance has been over-emphasized.[44] Witty and Kopel made a study of two groups of children. The poor readers were the 100 poorest among 1000 children whose I.Q.'s were above 80. The controls were 100 children who were reading up to or above grade placement level. They found that 29 per cent of the poor readers and 1 per cent of the good readers exhibited slow or sluggish fusion.[45] The above evidence would indicate that binocular incoordination does not differentiate the good reader from the poor reader. I have observed that among poor readers who have a vertical imbalance as determined by the Betts Visual Sensation and Perception Tests, there is a tendency for the child to lose his place in reading. This is evidenced during the return sweep, as they may skip a line. This is especially true if they have a condition known as *alternate fixation*. By the same token, the same condition might be found among poor readers who have a lateral imbalance. In this event, there would be a tendency to skip words, thereby losing the continuity of the sentence. If we have conditions of vergence during the actual reading process as I described earlier, binocular incoordination could cause ocular discomfort. Any condition which causes ocular discomfort will certainly discourage reading. And there is no way known to us that a child can learn to read, except by reading. And, by the way, the emphasis has changed from *learning to read* to *reading to learn*.

Fusion. In regard to fusion, there is conflicting evidence. Some writers believe that slow fusion can be a differentiating factor in separating the poor readers from the good readers. Others think that this visual factor is over-emphasized. I have observed that among the reading disability cases at the Reading Laboratory of the University of Pittsburgh was found a high incidence of slow or sluggish fusion at the near point as measured by the Keystone Tele-binocular. It is a well-known fact that man can compensate to a high degree for some visual anomalies. Slow learning in reading, especially in the early grades, may be accompanied by inaccurate binocular co-ordination or sluggish fusion. I sincerely believe that slow or sluggish fusion is the direct or indirect cause of more reading failures than the records show.

DOES PROLONGED READING PRODUCE VISUAL FATIGUE?

Does prolonged reading cause visual fatigue? Can a person read for several hours without experiencing ocular discomforts? Do four to six hours of continuous studying produce any deleterious effect upon the eyes? Several workers in the field of reading have attempted to answer these questions. Before I describe experiments designed to measure any manifestations of *visual fatigue*, let us consider for a moment a definition

of *visual fatigue*. When we say that a person is fatigued or tired, we usually mean that he has experienced some discomforts that will lessen his efficiency. Should we use "discomforts" as a criteria? When you feel tired, are you really tired? Is this attitudinal change a valid criteria for determining whether a person is fatigued? Tiredness is manifested in many ways. Which of these manifestations is a valid criteria for determining a state of fatigue? Certainly, a *work decrement* is a valid criteria for determining whether or not a state of fatigue exists.

Carmichael and Dearborn[46] conducted an extensive experiment designed to measure any evidence of visual fatigue. In other words, they attempted to measure any evidence of *work decrement* while the subjects read continuously for a period of six hours. Forty persons participated in the study: they were divided into four groups. Two groups were college students and two groups were high school students. Each subject read from two books—one a historical novel, "Lorna Doone," and the other an eighteenth century treatise on economics, titled, "An Inquiry into the Nature and Causes of the Wealth of Nations." Twenty of the subjects read the books directly: the other twenty read a projected version from microfilm. The projection of the microfilm was such as to reproduce the same format as in the books directly read. The particular typographic format selected was the result of the findings of research in this particular area. The evidence found seemed to support a ten-point type, Old Style, medium boldness, set solid, on dull-finished, cream colored paper as optimal for the study. The line length was 88 millimeters and there were 44 lines per page, with an average of 12 or 13 words per line. By the use of an Electro-Oculogram a record of the movements of the eyes was made for the six-hour reading period. The following measures were obtained by the use of this apparatus: number of lines read, number of fixations, number of regressions, and number of blinks. Both an electrocardiogram and an electroencephalogram were also made during the reading process. By the use of an ink-writing oscillograph, a continuous record was made during the six-hour reading period. To facilitate the statistical analysis, a sample was taken for a five-minute period during each half hour, thereby giving 13 samples (two samples taken for the first half hour, one at the beginning, and one at the end). The reading was done in a specially built room or cubicle shielded from stray electric currents and sound-proofed as much as possible. Certain rapid tests were made of the subjects' visual acuity and stereoscopic acuity before and after the six-hour reading period. Interspersed throughout the reading material were check tests designed to measure the efficiency with which the material was read. These were

spaced every 25 or 30 pages. Also, at the end of the six-hour reading period a comprehensive reading test was administered to each one participating in the experiment.

The facts gleaned from the electrocardiogram and the electroencephalogram have not been published as yet by the authors. As a result of casual observations, the authors have this to say, "Casual observations of these six-hour long electrocardiograms seem to indicate a greater variability of heart rate and of the form of the electrical wave than would have been anticipated."[47]

Quoting further from the authors, we have their general conclusions, "the first conclusion . . . is that significant changes were not found in the various measured aspects of the eye's behavior in reading during an experimental six-hour period."[48] The inference here that a normal subject, who does not have any eye anomalies which cannot be corrected, can read continuously for six hours without undue signs of fatigue, is important in planning many types of visual work. Furthermore, there seems to be no basis for the belief that long periods of reading on the part of secondary school or college students will be injurious to the visual mechanisms of such students if they have satisfactory visual performance.

A second general conclusion is that both the college and high school students evidenced no work decrement while reading the microfilm projection of the two books.[49] One exception is that one group of high school students read the microfilm reproduction less well than they did the books. This was true in regard to eye movement as well as to tests of comprehension.

Some very interesting facts may be gleaned from the results of the experiments: The average blink rate for each five-minute period for the reading of "Lorna Doone" was 66.6 and for "Wealth of Nations," 79.8.[50] It is interesting to note that the number of fixations per line was 8.6 for "Lorna Doone," and 7.9 for Adam Smith's book.[51] An average of 127 lines were read by each subject in "Lorna Doone," and 131 were read in "Wealth of Nations."[52] It was noted that less regressions were made in the reading of "Wealth of Nations" than in "Lorna Doone."[53]

"LORNA DOONE"

	Blinks	Fixations Per Line	Lines Read	Regressions Per Line
Normal Reading	66.6	8.6	127.6	2.20
Microfilm Reading	44.4	8.5	137.9	2.41

"WEALTH OF NATIONS"

	Blinks	Fixations Per Line	Lines Read	Regressions Per Line
Normal Reading	79.8	7.9	131.2	1.88
Microfilm Reading	51.8	8.1	134.6	2.96

The above figures are the averages for the 13 sample periods taken. It would appear from the above data that projected microfilm can be read as easily and as rapidly as normal printing, and that there is no evidence that microfilm reading produces any manifestations of visual fatigue.

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THE ASSOCIATION OF SCHOOLS AND COLLEGES IN OPTOMETRY

From the standpoint of the profession it is both pleasant and significant to report that the Association of Schools and Colleges in Optometry held one of the finest and most successful meetings in its history, preceding the annual Congress of the A.O.A. at Rochester, New York.

The four-day session adhered closely to a heavy agenda and showed our educators to be working in complete harmony and with the best interests of the profession in mind. It showed them to be acutely aware and active in solving those problems which are peculiar to professional undergraduate optometric education.

Dr. Kenneth B. Stoddard, Dean of the School of Optometry, University of California, has served as President of the Association during the past two years. Dr. Stoddard presided at the meetings. The acclaim he received from the school administrative men present indicated that he has done an admirable job for all schools and colleges during this period. Many Committees have been active—working on the questions and problems which have been before the Association. At the meeting these committees submitted their reports and as a result many spirited discussions took place.

Among the matters discussed were the following:

Collective work on the part of all schools to improve undergraduate enrollment, and the responsibility the profession itself has in this activity.

The need for a public relations effort directed towards the optometrists in practice to make them better informed on the outstanding educational progress being made in our schools and colleges and on the future progress which is sure to come in these educational centers.

The entire question of scholarships and fellowships.

The important matter of handling student transfers.

The relations between the schools and colleges and the State Boards of Examiners in Optometry.

The advantages to optometric education in better interprofessional relationships and the need for keeping up the work of the National Interprofessional Committee on Eye Care.

The overall question of textbooks and the need for securing advanced and suitable ones for the future.

The whole faculty question and the need for more educators thoroughly trained in the basic sciences for present and future use in our educational centers.

The six-year program in undergraduate optometric education and the professional degree.

The need for improved physical plants and finer equipment as a better aid in teaching.

The need for cultivating an appreciation and understanding of professional responsibilities in the student body and also an understanding of the relationship of optometry and other professional groups.

In the field of harmony and unity among our schools and colleges it was proposed that the optometric press adopt a uniform method of designating all schools in like manner.

The need for more applied and clinical research in our schools and colleges and the need for grants-in-aid for this purpose.

The need for educational representation for optometry on the National Interprofessional Committee on Eye Care.

These and other problems were discussed and many important conclusions were reached. The meeting, which lasted four days, was marked by constructive action on current problems and a genuine attempt was made to anticipate future problems and be prepared to overcome them.

The schools and colleges were represented at the meeting by Presidents, Deans, faculty and administrative men and Trustees.

Dr. Henry W. Hofstetter, Director of the Division of Optometry, Indiana University, was elected President to succeed Dr. Stoddard. Dr. Charles Stewart, Dean, College of Optometry, University of Houston was elected Secretary-Treasurer, and Dr. Eugene Freeman, Dean, Chicago College of Optometry, was elected member of the Executive Committee.

The entire meeting was marked by constructive leadership and the type of unity which makes further progress in optometric undergraduate education a certainty. Optometry is fortunate indeed in the overall caliber of its administrative leadership now directing our schools and colleges. The Association which represents this important group has been in fine hands—and will continue so under its new officers, of whom much is expected.

CAREL C. KOCH

SPECIAL REPORT

LEGALISM IN ETHICS*

Eugene Freeman†
Chicago College of Optometry
Chicago, Illinois

One of my first insights into ethical theory was the awareness of the acute contrast between *compulsion* and *persuasion* as sanctions for morality.

For many years, I have been occupied in my lectures, in my reflections, and in an occasional paper, with the implications for pro-

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†Optometrist, Ph.D. Dean of College. Fellow, American Academy of Optometry.

fessional ethics which follow from an awareness of the limitations—both in purposes and methods—of seeking ethical improvement, either through compulsion or through persuasion. An exploratory statement of some of these differences was made in a paper called "The Good Guys and the Bad Guys" which I wrote for the OPTOMETRIC WEEKLY in 1944.

What I propose to do in the present paper is to re-examine this problem, and consider specifically the limitations of compulsion as exerted through legal statutes as a mechanism for the elevation of professional standards and conduct. Both the advantages and disadvantages of *compulsion*, or *legalism in ethics*, will be considered.

There are certain areas of conduct, and certain stipulations concerning conduct, which experience has demonstrated must be expressed in the form of taboo or legal prohibition, according to the general formula "don't do this or else such and such a specific punishment will follow." Here the underlying presupposition is that of Hobbes—man's actions are nasty, brutish, and selfish—only the fear of punishment restrains man from immorality and vice—a man will refrain from those immoralities which carry with them the risk of sufficiently drastic punishment.

Opposed to the Hobbesian view is the idealistic view of Plato and his successors, that no man voluntarily chooses anything but the good—that when he chooses evil it is through a mistake—that no man who understands what is *good* or *right* can choose anything else for himself but to follow it.

Much of the language in a professional code of ethics is Platonic in the above sense. It is based on the presupposition that there are men who choose to be professional not through fear of punishment for unprofessional conduct, but because professional conduct is right and good, and is its own reward.

It is important to bear in mind that there are two frames of reference in which questions of professionalism fall, and that it would be disastrous to fail to keep these two frames of reference separate. One frame of reference is optimistic and idealistic; the other frame of reference is pessimistic and cynical. In the past I have distinguished these two frames of reference by designating them as the language with which we speak to either the "good men" or the "bad men." The ideals and ethical exhortations of a professional society as formulated in a code of ethics obviously fall into the optimistic or idealistic frame of reference —the language for the "good men." The statutes of a branch of government which incorporate statements of defined violations of the

law, and of the range of punishments which the law provides for the defined offenses, clearly belong to the pessimistic or cynical frame of reference—the language addressed to the "bad men."

At this point it would be perhaps painfully obvious that nothing could be more futile than to address the cynics in optimistic language, or more insulting and useless than to address the optimists in cynical language.

There is a very real and important place for both approaches in the development of professional standards. Certainly if an average group, containing both idealists and cynics, were to be regulated only by the optimistic language of the idealist, with no external compulsions upon them to refrain from wrong-doing, the cynics in the group who repudiate the dictates of conscience and the good opinions of others would ruthlessly take advantage of their colleagues and the public.

If, on the other hand, such a group were to be regulated only by the negative taboos and prohibitions by means of which the law defines the various specific ways in which conduct can be anti-social and illegal, and defines the penalties for these specifically designated forms of immorality, the code would have a very limited effect. It would restrain, in specific ways, certain actions of the cynics who might otherwise have engaged in illegal activities. It would, however, be almost wholly irrelevant as a guide to the conduct of the optimists or idealists, at least to this extent. The law would tell them that certain actions were wrong, but it would throw no light whatsoever on the bigger problem as to what actions are right. But what the optimist needs is clarification of what he ought to do, that is, of what conduct is ethically approved, because if it is right, then he wants to follow it. At the risk of laboring the point, which is probably obvious by now, the optimist obeys the law, not because he is afraid of the punishment, but because he feels that the law is right. This is the reason that laws alone can never replace ethical ideals—why the fear of punishment can never replace the hope of reward.

I hope that an understanding of these principles will help our optometric leaders to avoid repeating some of the absurdities which have resulted from misplacing the two frames of reference, which must be kept apart if our planning for the profession is to be sound.

Perhaps we might put the matter this way: Legal statutes can only govern what is known as external conduct—that is, a man's words or a man's deeds. They cannot govern the secret thoughts or intentions which are locked up in a man's mind and heart. If a man breaks the commandment which forbids him to covet another man's wife, or if in

the private recesses of his own heart he has a secret wish, or hope, or intention, of committing a crime like theft or murder, there is no legal statute which could be drawn upon as a basis for prosecuting him, provided that he did not disclose by word or deed the covetous or avaricious or murderous wish or hope or intention which is within him. If, however, this intention impels him to speak or act in such a way as to make public and objective the fact that he is entertaining any of the above intentions, he can be prosecuted by law, not for harboring the intention, but for speaking or acting in such a way as to disclose that intention, even though he were to be unsuccessful in carrying it out.

It is, of course, morally wrong for a man to have a criminal intention, whether he acts upon it or not, but it is only for *acting* upon the intention that he can be punished by law. It is fortunate for all of us that this is so. Otherwise, we would probably spend most of our lives in jail.

Legal statutes which forbid various forms of wrong-doing on pain of a more or less appropriate punishment do have a tremendous force in preventing crime. It is possible that there are some people who are so saintly in their thoughts and in their actions that they would never either think of doing anything wrong, or voluntarily committing a wrong in word or deed. And there may well be different people who refrain from criminal action, not because crime is wrong, but only because they are afraid to risk the penalties of being caught. However, the number of people who are either perfectly good, or perfectly bad, is so small that there is very little reason for us to be concerned about them at all. Most people are both rational and irrational, both good and bad —the best of us are not above breaking an occasional legal or moral rule when it is to our advantage to do so, even though we know it is wrong. And I suspect that even the most depraved man retains some vestiges of moral guilt, and anxiety of conscience, in at least certain areas of his conduct. In short, the distinction between the "good men" and the "bad men" or the optimists and the cynics, or those who can be reached by either compulsion or persuasion but not by the other method, is hardly more than a figure of speech. For practical purposes we mean by the "good man" not the man who is morally perfect, but the one in whom there is more good than bad. And the reverse is true of the "bad man," in whom we can always find *some* good.

Nevertheless, even though the distinctions we make can never be more than approximations, and admittedly there is a danger that they could become abstract stereotypes for which no living counterparts could exist, we can still distinguish for *practical purposes* between those

members of our profession who for the most part *cannot* be persuaded to accept voluntarily the external restrictions which professional men impose upon their conduct, and those who *can* be so persuaded. It is for the former group, whom we can designate as the "bad men," for whom our statutes are primarily written.

This does not mean that I am proposing the absurdity that our so-called "good men" would be just as moral and law-abiding as they are now if there were no penalties accruing to law breaking as there are under our present system. Instead, what I am concerned about is a simple but basic principle of the philosophy of law. The *compulsion which is inherent in legal statutes is a compulsion upon external conduct only*. Furthermore, the compulsion is a *negative* one, and its effect is to deter a potential violator from committing those overt actions which are defined as illegal. In a word, what the law does, insofar as it is effective, is to force a man to refrain from wrong-doing. But legal compulsion in itself has no *positive* effect in the elevation of the moral level of men's actions, at least in respect to particular cases as opposed to the cumulative effect of many years of habitual conformity to law.

For this positive force we must turn to the persuasive power of ethical ideals, which are self-imposed, and are obeyed because of their rationality and their beauty and their goodness, rather than through any external compulsion, or force, or threat of punishment.

And now, to illustrate the two frames of reference, and the mistakes which may be made in failing to keep them apart, let us consider some specific examples. Even the legal profession is not free from the confused thinking that results from a failure to take into account adequately the nature and limitations of legal compulsion, and to attempt to accomplish by compulsion what can only be brought about by voluntary and free acceptance of moral ideals. In the 1950 statutes of the Commonwealth of Iowa, for example, under the "Rules of Civil Procedure" (section 610.14) the duties of attorneys or counselors are stipulated according to the law, and under the penalties of disbarment and triple damages. It is apparent on even the most casual reading that only one of the seven sub-sections is objective enough to be enforceable by law, and that all the other sections are merely ethical exhortations which belong in the code of ethics but are out of place in the statutes. This is most flagrantly true of sub-section 7, which stipulates that it is the duty of an attorney and counselor "never to reject for any consideration personal to himself the cause of the defenseless or oppressed." This poetic statement is so high-flown and idealistic (and obviously unenforceable by law) that it has actually

been cast into the form of blank verse, perhaps out of an unconscious deference to the other-worldliness of the ethical principle involved.

Another sub-section (No. 1) obligates the lawyer "to maintain the respect due to the courts of justice and judicial officers." But this cannot be forced by law, since a lawyer who does not maintain the respect due to judicial officers and courts cannot be detected and punished unless he expresses by word or deed a *disrespect* for the court or judicial officer. Here, again, the law can deter negatively, it can compel forbearance from wrong-doing, but it cannot through force compel a lawyer who does not voluntarily choose to do so to perform a positively right action.

This example from the field of *legal* ethics and jurisprudence has been cited not for the purpose of justifying whatever similar weaknesses we may find in optometric codes, but in order to underline the difficulties and perplexities which are encountered by those leaders who try to raise the level of practice of a profession. How much can they do by legal compulsion—and how much can they do by ethical persuasion? When must one technique be employed and not the other? And what is the effect of using the "wrong" technique?

One of the typical rules in the Code of Ethics of the American Optometric Association *(Supplements—Part I, Sec. D* entitled *Personal Deportment)* stipulates that "an optometrist must be an upright man. Consequently he must keep himself pure in character, must conform to a high standard of morals, and must be diligent and conscientious in his studies."

This is language addressed to the good man, and it is self-evident that it does not belong in a statutory code, nor is it usually found there.

Another provision in the same section of the Code of Ethics—Section B, entitled *Self-Improvement* stipulates that:

> "It is the duty of every optometrist to keep himself in touch with every modern development in his profession, to enhance his knowledge and proficiency by the adoption of modern methods and scientific concepts of proven worth, and to contribute his share to the general knowledge and advancement of his profession by all means in his power. All these things he should do with that freedom and action and thought that provides first for the welfare of the public within the scope and limits of his endeavor."

Take, for example, the very worthy efforts which have been made by leaders in our own profession to insure that every optometrist should fulfill the basic obligation of the profession which requires him to keep abreast of all of the new developments in his field. They have made every possible assistance available to any optometrist who has voluntarily accepted this obligation and wants to fulfill it.

The journals are filled with voluntary and freely made contributions to the art and science of optometry. The colleges, the

Academy, the American Optometric Association, the Optometric Extension Program, and the state and local optometry associations have made available post-graduate courses, seminars, extension courses, study groups, and educational lectures, which encompass virtually every new development in the field, and which turn these developments over to the profession just as soon as they are made.

Nevertheless, there are some optometrists who apparently are sufficiently indifferent to the ethical obligations of this ideal of professional conduct so that their colleagues (in a small number of states) have incorporated a provision into the Optometry Act which is designed to compel them by force to keep up with recent developments. Such regulations usually stipulate that in order to be eligible to have his license renewed, the optometrist, in applying for annual renewal, must also submit to the Board of Registration and Education a card signed by an officer of the state association certifying that he has attended a stipulated number of officially recognized educational sessions during the preceding year.

What is the effect of this provision in the law? Can it force a man who does not, of his own accord, wish to keep abreast of current developments, to do so against his will? Unfortunately, it cannot. It can force him to attend a state convention, and it can force him to get his ticket punched at the beginning of a prescribed number of educational meetings. But it cannot force him to listen if he does stay at the meeting, nor to apply what he has learned, if he does listen—to say nothing of the fact that he is just as likely to leave as soon as his ticket has been punched and spend the hour at the bar, instead of at the session.

Here, I suppose, is what this all comes to. You can bring an optometrist to a convention where you have set up a bar at which educational lectures are served, but if he has a different kind of thirst he can always find a congenial kind of bar where something more to his taste is served. In short, you can lead an optometrist to a convention, but you can't tell him what to drink.

If these legal statutes are designed to compel any reluctant optometrists to submit to being *forcibly* educated by their colleagues, I see no escape from the unwelcome but inevitable conclusion that such statutes are futile, and are foredoomed to failure.

But, even if this is the case, it might be argued—aren't there others who are not unwilling to be educated, but through inertia, or the pressure of others affairs, might have stayed away from the conventions or seminars if they had not been compelled to attend? And then, since they are there anyhow, don't they go to the lectures, listen carefully,

profit from them, apply what they learn, and aren't they grateful for the compulsion which brought them there?

Granted! But what is the impact of the statute on those who go to these meetings voluntarily, and not because they are forced to do so by law? And what is the impact of these statutes on the professional status of optometry, as compared with other professions?

It seems to me that the men who voluntarily attend the meetings are demeaned, and the profession is debased, by the very existence of these statutes. There is a vast and virtually unbridgeable gulf which separates those who voluntarily accept ethical ideals and, of their own free will, try to do what the profession feels to be right, and those who refuse to accept these ideals, and whose conduct is determined in a negative fashion by the brute force of the threat of punishment for wrong-doing. These statutes, in effect, are an insult to the "good men" in the profession, to whatever extent the existence of the statute implies that the "good men" are doing what is ethically right not because they want to, but because they have been forced to by law. And, for very much the same reason, these statutes are an insult to the profession, to whatever extent they imply that an ethical principle which is voluntarily accepted by other professions can only be carried out by force in our own profession.

It has been said that, ideally, every provision in our optometric codes of ethics should be incorporated into our statutes. That this is a mistake should now be apparent. Statutory regulations are negative—they can do no more than to deter us from doing wrong. Ethical regulations are positive; through them we can be *persuaded* but *not forced* to choose to do what is right. Now, to revise and apply an ethical principle, formulated by Immanuel Kant, who held that the only *moral action* is one which is done for the sake of duty alone, we can say that a right action which is performed *involuntarily* has no moral worth. Only an action which is voluntarily chosen because of its rightness is worthy of moral praise. A profession, then, which is ethical to any extent through legal compulsion, is to that extent not worthy of any moral praise for being so. Insofar as it might have been ethical through free choice, instead of compulsion, it is deprived of the moral worth it could have accrued, and in that measure it is debased. Similarly, to imply that an individual who has voluntarily chosen to do what is right has done so because he has been forced to do so by an external compulsion, is to deprive him of the moral worth of his action. To do this is to insult him.

We are thus driven to the conclusion that to transfer an ethical

ideal from a code to ethics into a code of legal statutes may very well be a mistake, because it deprives the practitioner and the profession of the credit they would otherwise gain for freely choosing to accept the ideals of professionalism. Furthermore, as has been pointed out, and as is easily apparent when any further examples are considered, it is completely futile to incorporate into the statutes any ethical ideal which pertains to "internal" rather than "external" conduct. A man's words and deeds can be regulated by law, because violations are objective and can be proven. A man's thoughts, his hopes, his aspirations, his ideals, cannot be regulated by law, because they are private and violations cannot be proven or punished. At least this is still true at our present level of technological development, although, as Orwell hinted in his grim novel of the future, entitled *1984*, the day of thought-control and mind-police may be not too far away.

Let me hasten to add, however, that it is only those ethical principles which refer exclusively to *internal* conduct and are accordingly intrinsically unenforceable, which we should avoid incorporating into our optometry law, except for a single blanket provision which ostensibly makes the entire code of ethics part of the statutes. Even under such provisions, however, none of the rules governing internal conduct are *actually* part of the law. Where an ethical principle legislates *external conduct*, with the consequence that violations are *provable* and therefore punishable, we can incorporate the principle into the statutes without any regard for the loss of prestige suffered by the practitioner and the profession when we are compelled by law to be ethical. This is because the prestige gained in protecting the public health and welfare from unscrupulous practitioners who would otherwise exploit the public, to say nothing of the indispensable protection which the ethical members of the profession gain against unfair competition from unethical colleagues, far off-sets any prestige that is lost by putting the rule into the statutes. That our lawmakers themselves recognize and endorse the principles stated above is clearly and eloquently proven by the recent unanimous opinion of the Supreme Court of Illinois in upholding the new (1951) Illinois Optometry Act. The opinion is a memorable one—it is a landmark in optometric legislation and should be read carefully by every optometrist who is interested in the betterment of his profession.

The Illinois Act incorporates into the statutes a certain number of the excellent rules of practice of the American Optometric Association which legislate external conduct and are thus objective, provable and enforceable. I will close this paper by quoting one brief section of the

opinion in which the Court has incorporated one of the simplest, the clearest, and what could very well become one of the most influential lessons in professional ethics that optometry has ever been privileged to read.

"While at first blush it would seem that sections 13 (k), (l) and (m) appear to be an arbitrary interference with the right of one to practice optometry, such thoughts are dispelled when the relative aspects of public health and welfare are considered. As pointed out in *Semler v. Oregon State Board of Dental Examiners*, 294 U. S. 608, 79 L. ed. 1086, the legislature is not dealing with traders in commodities but with the vital interest of public health and the treatment of bodily ills. The public is concerned not only with the maintenance of standards which will insure competency in the individual practitioner, but protection against those 'who prey upon a public peculiarly susceptible to imposition through alluring promises of physical relief.' In addition, the community is concerned in providing safeguards not only against deception, but against practices which tend to demoralize the business or profession by forcing its members into unseeming rivalry, which would tend to enlarge the opportunity of the least scrupulous. Advertising by large display, glaring and lighted signs or by depicting a part of the human body, and other forms of advertising, have been held to produce such undesired results and accompanying detriment to the public welfare. (*Winberry v. Hallihan*, 361 Ill. 121.) In the case last cited and in the Semler case, it was held that the legislature was entitled to consider the general effects of the practices it described, and, if the effects were injurious in facilitating unwarranted and misleading claims, to counteract them by general rule even though in particular instances there might be no actual deception or misstatement. This the legislature has done in enacting sections 13 (k), 13 (l) and 13 (m) by restricting the advertising of optometrists within limits which are reasonable and calculated to eliminate the injurious effects of uninhibited advertising. Such legislation comes within the police power and is valid. *Winberry v. Hallihan*, 361 Ill. 121."

In plain language, this is what the Illinois Supreme Court has said. An ethical practitioner cannot defend himself against unfair competition because his code of ethics forbids him to, and unless the ethical man wins, the public health and welfare suffer. Therefore, since the commercial optometrist will never lay down his brass knuckles of his own accord, it is necessary for the court to take them away from him, and in a fair fight ethical optometry will win, and only then can the public win.

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

REPORT ON THE SHEARD COMMEMORATIVE VOLUME

Work on the Commemorative Volume in honor of Dr. Charles Sheard has been moving along at a satisfactory pace. From the money side, in late August when this report was written, the optometric committee working on the project had secured somewhat more than 215 subscriptions for a total of about $4,000.00, and additional subscriptions

from *friends of Sheard* among the optometrists of the United States and Canada were coming in daily.

In addition in opticianry a committee has been set up to assist this fine project. These committee members join the optometrists on the committee whose names have already been announced. Mr. Henry B. Carpenter, Syracuse; Mr. Robert F. Duffens, Topeka; Mr. Arthur G. Hager, Chicago; Mr. Norman A. MacLeod, Providence; Mr. Leslie W. Myers, Minneapolis; Mr. Herbert L. Ridgeway, Jr., Raleigh; Mr. Walter A. Stewart, Southbridge; Mr. Russell L. Stimson, Los Angeles; Mr. Joseph F. Taylor, Rochester, N. Y., and Mr. Arthur F. Williams, St. Paul. Under their leadership the *friends of Sheard* among the opticians have secured about 50 subscriptions totaling about $1,000.00 and expect to secure more.

A report on similar activity from *friends of Sheard* among the physicians and ophthalmologists of America is expected early in September.

From the standpoint of funds, the program is making good progress although we have not as yet reached the necessary goal of $8,000.00. All readers wishing to help make this activity a success should send their check in the amount of $10 to $25 to the American Academy of Optometry—Sheard Fund, 1502 Foshay Tower, Minneapolis 2, Minn. Each subscriber will receive a prepaid copy of the commemorative volume when printed—have his name included in the list of *friends of Sheard* in the book itself—and will have the great satisfaction of having participated in an outstanding event which will give pleasure to a fine man. In addition it appeals to the higher principles of all persons working in the field of vision, as Dr. Charles Sheard has made, during his fruitful life, so many significant contributions to our work.

As to the book itself—Dr. Meredith W. Morgan, Jr., General Chairman of the Committee, after conference with Dr. Sheard has approved the general outline and contents of the book which will contain six parts.

Part I will consist of reprints of Editorials, Reviews and Abridgments of Articles which were written by Dr. Charles Sheard in the period 1920-1926 and which for the most part appeared in the AMERICAN JOURNAL OF PHYSIOLOGICAL OPTICS. These essays—from 15 to 25 of them—will be selected for publication from a larger list of his early writings on vision.

Part II of the book will be a complete reprint of his early work, "Dynamic Ocular Tests" which was published in 1917. This section of the book will run about 150 pages and in itself forms the clinical and

scientific background for many of our refractive tests of today.

Part III will be entitled "Dynamic Skiametry and Methods of Testing Accommodation and Convergence of the Eyes." This material was first published in 1920. This section of the book will run slightly over 100 pages.

Part IV will consist of "Essays and Contributions on the Problems of Binocular Single Vision." from the writings of Dr. Charles Sheard on these subjects from 1930-1940.

Part V will deal with "Ophthalmic Optics." Here will be reproduced some of Dr. Charles Sheard's early writings on Lenses, Prisms, Optics. Transmission of Radiant Energy and similar important topics.

Part VI will consist of "Selections from Researches and Contributions to Special Topics in Visual Science." Here his scientific writings in such fields as dark adaptation, glarometric and photometric measurements and the tolerance of the human eye to light, will be presented.

It is evident that such a book will have not only great sentimental value but also have a real place in our literature. These collected writings of a lifetime by a great scientist will prove to be a contribution to the future education of all in this field of health work.

There is still time to become identified with this project. Every optometrist—optician—and ophthalmologist is invited to subscribe to help us all honor one of our great men in his 70th year and to assist in perpetuating his now scattered early writings which in many instances are now out of print. Send your subscription to the Sheard Commemorative Volume Fund to the American Academy of Optometry today and join us in making this commemorative project an outstanding success.

ANNUAL MEETING OF ACADEMY

CHICAGO, ILLINOIS, DECEMBER 5-8, 1953

Advance reports from the Papers and Program Committee indicate that among the speakers at the annual meeting of the Academy in Chicago, December 5-8, 1953, will be the following optometrists and scientists. Dr. Edwin W. Bechtold, Columbia University; Dr. C. F. Schumacher and Dr. A. R. Lauer, Iowa State College; Dr. Francis A. Young, Washington State College; Dr. Merrill J. Allen, The Ohio State University; Dr. Israel Dvorine, Baltimore; Dr. Elwin Marg, University of California; Mr. Fred Jobe, Bausch & Lomb Optical Company; Dr. Sylvester K. Guth, General Electric Company; Dr. Eugene Freeman, Chicago College of Optometry; Dr. Joseph I. Pascal, Polyclinic Medical School; Dr. Glenn A. Fry, The Ohio State Univer-

sity: Dr. Emmanuel Gobeil, Clinique de Rehabilitation Visuelle: Dr. M. Kirschen, Modesto, California: Dr. Arthur Shlaifer, Pennsylvania State College of Optometry: Dr. Mathew Alpern, Pacific University: Dr. John R. Kennedy, The Burch Clinic, St. Paul: Dr. George A. Parkins, Ord, Nebraska: Dr. William Schumann, Vineland, New Jersey: Dr. V. J. Ellerbrock, The Ohio State University: Dr. T. R. Murroughs, Northern Illinois College of Optometry: Dr. Charles Sheard, Rochester, Minnesota: Dr. Alfred A. Rosenbloom, Northern Illinois College of Optometry: Dr. Meredith W. Morgan, Jr., University of California: Dr. Frederick W. Sinn, Pennsylvania State College of Optometry: Dr. Gerald Westheimer, University of Houston: Dr. Z. J. B. Schoen, Chicago College of Optometry.

The names of additional speakers and the titles of all papers will be announced in a subsequent issue. This coming four-day meeting of the Academy will be held at the Drake Hotel, Chicago. Dr. John D. Perry, Jr., is Chairman of the Papers and Program Committee.

CURRENT COMMENTS

Terry Judith Parkins
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department: such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

STYLE AND POWDER ROOM FOR WOMEN PATIENTS

Years ago, as a small girl, I remember how my mother suffered from headaches. She had them very frequently and used to go to bed because of them. There she covered her forehead and eyes with cold damp cloths. We children then had to be real quiet. Finally someone suggested that she have her eyes examined and after getting glasses she no longer had these spells of "sick" headaches. I remember well, how glad we all were that she was better, yet how as a child I thought her glasses made mother look much older.

Today with modern styling of frames in all colors, designs and shapes, this would not be true. In fact for many women today's glasses, when properly selected and styled for their particular use, add to their charm and sparkle. Many middle aged and elderly women in fact look younger because of the chic and smartness of their glasses.

Slowly over the past 25 years, styles in glasses have taken on a more important aspect of optometric practice. No longer is it only

essential to know how to examine and refract and to properly take facial measurements and to carefully adjust frames or mountings. Today's progressive optometrist must also be able to service his patients in the matter of appearance as well as visual comfort.

Our most successful optometrists make every effort to please their patients in this last phase of their work, just as they do in the scientific parts of their work. These men know that their job is not completed when they prescribe correctly fitted glasses. The glasses must satisfy the style minded patient in both the therapeutic and aesthetic senses. Only when this is accomplished—and it is not an easy job—are we sure that another loyal friend has been made for our profession.

This whole matter of style in glasses is time consuming for the optometrist and in this end of our work an efficient office girl who has been trained and who is style conscious herself can be of real help to the busy optometrist.

After the examination and refraction has been completed, the patient wishing one or more new seeing outfits is taken into a separate dispensing room by the office girl and is there shown various appropriate frames while the optometrist is working in the refracting room on another patient. After the frame or frames have been selected, the optometrist excuses himself and comes to the dispensing room to take the necessary facial measurements needed to start the prescription to the laboratory.

In fact this matter of styling in glasses is considered so important in one office that a special mirrored powder room has been set aside for women patients only, where the styles in glasses are then shown the patient by an office assistant who has a flair for this type of specialized work. After the selections have been made the patient is then taken to the dispensing room where the optometrist takes the needed measurements. In this office children and men patients are shown their styles in frames in the dispensing room by the optometrist himself, or by his office assistant.

This attention to styling proves popular wherever attempted by optometrists. It is an essential part of their complete visual service and is greatly appreciated by many style conscious patients—and who is *not* style conscious today?

ASSOCIATION OF SCHOOLS AND COLLEGES OF OPTOMETRY

The Association of Schools and Colleges of Optometry announces the following appointments to standing committees for the year 1953-54:

Committee on Educational Policy: Dr. C. B. Margach, Chairman, Pacific University; Dr. C. R. Stewart, University of Houston; Dr. Alfred Lit, Columbia University; Dr. Frederick Hebbard, University of California and Dr. Eugene Freeman, Chicago College of Optometry.

Committee on Personnel and Administration: Dr. Frederick Kushner, Chairman, Northern Illinois College of Optometry; Dr. V. J. Ellerbrock, Ohio State University; Dr. E. J. Fisher, College of Optometry of Ontario; Dr. Henry A. Knoll, Los Angeles College of Optometry and Dr. M. E. Broom, Southern College of Optometry.

Committee on Textbooks and Publications: Dr. Gerald Westheimer, Chairman, University of Houston; Dr. Charles Abel, Los Angeles College of Optometry; Dr. O. N. Cole, Southern College of Optometry; Dr. Carel C. Koch, Chicago College of Optometry and Dr. Merrill Allen, Indiana University.

Committee on State Board Affairs: Dr. Joseph Ziff, Chairman, Los Angeles College of Optometry; Dr. Carol Pratt, Pacific University; Dr. Herbert G. Mote, Ohio State University and Dr. Arthur Schlaifer, Pennsylvania State College of Optometry.

Committee on Membership and Accreditation: Dr. Gordon Walls, Chairman, University of California, and Dr. Leslie G. Wright, Jr., Massachusetts College of Optometry.

7TH EDITION—MAC ELREE—OCULAR PATHOLOGY, OUT IN OCTOBER

The Press of the Pennsylvania State College of Optometry announces that the Seventh Edition of the *Manual of Ocular Pathology for Optometrists* by Dr. George A. Mac Elree, Philadelphia, is coming off the press October 1. This new edition of 560 pages has been completely revised and 74 new illustrations have been added. This special text with emphasis on diagnosis is especially written for optometrists and has proven to be an invaluable aid to both students and practitioners. For a limited time advance copies may be had for $10.50. Orders should be sent to the College Book Store, Pennsylvania State College of Optometry 6100 N. Twelfth St., Philadelphia 41, Pennsylvania.

CANADIAN ASSOCIATION OF OPTOMETRISTS

The second biannual meeting of the Canadian Association of Optometrists was held in Montreal, Province of Quebec, July 5-7. Dr. Harold Simmerman, Pennsylvania State College of Optometry and Dr. Monroe J. Hirsch, formerly of the Los Angeles College of Optometry, were two of the invited speakers at the educational sessions. At this meeting the following optometrists were elected. Dr. C. A. Palmer, R. O. Lethbridge, Alberta, President: Dr. W. M. Lyle, R. O., Winnipeg,

Manitoba, Vice-President; Dr. Eli Boyaner, R. O., St. John, New Brunswick, Secretary-Treasurer. The Executive Committee is composed of the officers and Dr. G. Darimont, R. O., Vancouver, British Columbia; Dr. N. C. MacGregor, R. O., Saskatoon, Saskatchewan; Dr. E. S. Lindo, R. O., Toronto, Ontario; A. Mignot, R. O., Montreal, Province of Quebec, and Dr. B. F. Hunter, R. O., Summerside, Prince Edward Island. The office of the association will be at 19 Richmond St. W., Toronto. The immediate past-president of the association is Dr. J. J. Mulrooney, R. O., Halifax, Nova Scotia.

DVORINE COLOR PLATES—SECOND EDITION

Dr. Israel Dvorine, Baltimore, designer and publisher of the Dvorine Pseudo-Isochromatic Plates, announces that he is issuing a second edition of his color plates for the testing of the red-green color blind. The new set has been condensed into one volume and contains the plates of the first edition which were selected by Dr. Louise A. Sloan of the Johns Hopkins Hospital as being highly diagnostic. Dr. Dvorine also designed a number of new plates for this edition as well as new color combinations not previously used. An innovation is a special section of plates designed for the testing of pre-school-age children and illiterates. Another new and exclusive feature is the mounting of the pages into a loose-leaf six ring binder to permit the examiners to change the sequence of the plates, if he so desires. The new set will be ready for distribution on or about October 1st.

NATIONAL BOARD OF EXAMINERS IN OPTOMETRY

The National Board of Examiners in Optometry met in Rochester, New York, on June 22 to conclude final arrangements for the second annual examinations scheduled for June 29 and 30 and July 1. Official action was taken in the appointment of supervisors, graders, and clinical examiners. Annual reports were made to the International Association of Boards of Examiners in Optometry and to the Association of Schools and Colleges of Optometry.

The secretary, Dr. John R. Uglum, reported that 209 new candidates had registered for the 1953 examinations. All of the A.O.A. accredited school and colleges of optometry were represented among the applicants.

Final arrangements were made for handling the complex details for Part III, the practical examination of the candidates' professional and clinical skills. Each candidate was examined by a practicing optometrist officially appointed as Clinical Examiner by the National Board. One of the major activities of the National Board during the

past years has been the selection and processing of a nation-wide panel of Clinical Examiners. Emphasis in screening was placed on known integrity, clinical ability, and professional demeanour for appointment to the panel. Advisors and consultants in this selection included association officials and state board officers.

The Part III examination consisted of a multiple series of clinical performance tests graded both on objective and subjective criteria. It is believed that this procedure has proved to be the most complete and informative practical examination ever employed systematically for the individualized testing of clinical and professional skills.

BACK ISSUES FOR PRINCETON UNIVERSITY LIBRARY

Princeton University Library is in need of the following back issues of the AMERICAN JOURNAL OF OPTOMETRY to complete their sets of annual volumes of this magazine and to permit their holdings of our issues to be bound, for permanent use by students and faculty.

Optometrists able to supply one or more of the following monthly issues are urged to write or send same direct to Princeton University Library, Princeton, New Jersey.

MISSING MONTHLY ISSUES*

Volume Number	Year	
7	1930	January; March; May; August; September; November and December.
8	1931	January; February; March; May; June; July; August; October; November and December.
9	1932	March.
10	1933	January; February; March; April and May.
12	1935	February; May; June; September and October.
14	1937	February; March; May and December.
17	1940	January and May.
18	1941	January and July.
19	1942	February.
20	1943	June; October and December.
21	1944	March and November.
22	1945	January.
23	1946	January; March; April; October and November.
27	1950	February; March; April; May and August.
28	1951	November and December.
29	1952	April.

*The Journal office is unable to supply the above monthly issues. Princeton University Library would also like to acquire all issues of the AMERICAN JOURNAL OF OPTOMETRY, Volume 1 through Volume 6. (1924-1929).

POST-GRADUATE COURSE IN ORTHOPTICS AND VISION TRAINING

The New Jersey Optometric Association and Rutgers University offer a post-graduate course in orthoptics with Dr. Daniel Woolf, School of Optometry, Columbia University as Lecturer. The course will consist of four terms of fifteen weeks each, with classes meeting for two hours once each week. The first term, offered in the current academic year in

Camden, begins Thursday, September 24, at 7:30 p. m. and continues through Thursday, January 14. The second term, offered in the current academic year in Newark, begins Tuesday, September 22 at 7:00 p. m. and continues through Tuesday, January 11.

First Term: Elementary and intermediate analysis and training procedures. Second Term: Advanced methods of analysis, such as graphical and extension program techniques; diagnosis of difficult training problems and techniques and training programs for these cases. Third Term: Diagnosis and training in strabismus, anomalous retinal correspondence, and related disorders. Fourth Term: Seminar and case discussions for guidance in the handling of problems arising in connection with cases of registrants.

The course in orthoptics and vision training has been arranged to provide a continuing program of postgraduate education in order to meet the demand of optometric practitioners for a means by which they may keep abreast of latest developments. For additional information optometrists should write to Dr. Paul Ellin, Department of Education, New Jersey Optometric Association, 162 West State St., Trenton, New Jersey.

NEWS BRIEFS

The Indiana Optometric Association was the first of the State Optometric Associations to subscribe to the Sheard Commemorative Volume Fund. The New York Academy of Optometry was the first Academy Chapter to make a similar group pledge. Each in the amount of $50.00. . . . Southern College of Optometry announces the appointment of Dr. Martin Ajemian who will join the faculty September 1 as head of the Departments of Anatomy and Physiology. Dr. Ajemian received his Ph.D. in anatomy from Georgetown University. For the last three years he has been a faculty member at Arkansas Polytechnic College. . . . The Optometric Extension Program announces the following five educational Congresses which are scheduled for the Fall months. Dr. A. M. Skeffington, director, will speak at each meeting. The North Central Congress in Minneapolis, October 11-13. Dr. H. Ward Ewalt, Pittsburgh, and Dr. N. C. Kephart, Purdue University, will be guest speakers. The New York All State Congress in Elmira, September 27-29. Dr. Fred Sutor, Philadelphia, and Dr. Kephart will be guest speakers. The Northeast Congress in Boston, October 18-20. Dr. George Crow, Los Angeles, and Dr. Marguerite Thoma Eberl, Milwaukee, will be guest speakers. The Middle Atlantic Congress in Pittsburgh (dates to be set), with Dr. Crow and Dr. Leo Manas, Chicago College

of Optometry, as guest speakers. The Heart-of-America Congress in Kansas City, November 8-10. Dr. Ward C. Halstead, University of Chicago, Dr. Ewalt and Dr. Crow will be guest speakers. . . . The Bay State Optical Company is now fully settled in their new plant in Westbury, Long Island, New York. . . . The 17th International Congress of Ophthalmology will be held at the Waldorf-Astoria Hotel, New York City, September 13-17, 1954. Dr. William Bennedict, Rochester, Minnesota, is Secretary-General of the Congress. . . . Dr. A. A. Rosenbloom, Northern Illinois College of Optometry was one of the speakers at the Workshop on Corrective Reading at the 16th annual conference on reading at the University of Chicago. . . . Division of Optometry, Indiana University is moving into larger quarters to be ready by the Fall term. . . . Bausch & Lomb Optical Company announce a new magnifying glass attachment for welding helmets. . . .

CORRESPONDENCE

FIELDS OF FIXATION

To the Editor:

In the July issue, Dr. Paul Miles pointed out that the values for the field of fixation were incorrect as stated in the paper "An Investigation of the Factors Affecting the Field of Fixation through Multifocal Lenses." The paper was published in this Journal in the April number, page 202.

The authors appreciate the acumen of Dr. Miles. The values mistakingly given the paper are the limits for the normal relative field of vision (Traquair, H.M.: An Introduction to Clinical Perimetry, 5th Ed., 1948, p. 6).

The field of fixation is the maximum angular rotation of the eyes with the head stationary. Approximate values for this field are 35° upward, 45° nasally, 55° downward, and 45° temporally, or 90° vertically and horizontally. (Laurence, L.: Visual Optics and Sight Testing, 1926, p. 63.)

K. S. ZINNECKER, M. SC., AND
V. J. ELLERBROCK, PH.D.

SCHOOL OF OPTOMETRY,
THE OHIO STATE UNIVERSITY,
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ANNOUNCEMENT

ACADEMY BOOKS NOW AVAILABLE

The American Academy of Optometry has available, a limited number of the following optometric books which it is offering to professionally interested persons who wish to enrich their libraries at a very modest cost. Each of these books, 6" x 9" in size is cloth bound and stamped in gold on the cover. These books will be mailed prepaid on receipt of order and the cost of the book or books. Checks should be made payable to the *American Academy of Optometry*. Selection should be made by number.

☐ Book No. 1. *Transactions of the 4th and 5th Annual Meeting of the American Academy of Optometry*. Vol. I. 1925 and 1926. Published in 1927. Original papers and reports by Drs. Eugene G. Wiseman, Carel C. Koch, W. H. Hammond, W. A. Mendelsohn, Francis P. Barr, R. M. Peckham, E. LeRoy Ryer, Elmer E. Hotaling, S. J. Owen, W. W. Coblentz and B. Woodward Hazell. 104 pages. Illustrated. Cloth bound. Price, $1.25.

☐ Book No. 5. *Transactions of the 9th Annual Meeting of the American Academy of Optometry*. Vol. V. 1930. Published in 1931. Original papers and reports by Drs. Briggs S. Palmer, J. Fred Andreae, J. I. Kurtz, George Oertel, J. Wolff, R. M. Peckham, Clyde J. Hathaway, Elmer E. Hotaling, E. LeRoy Ryer, C. R. Padelford, William Feinbloom, Sterrett S. Titus, R. E. Littlefield, A. M. Skeffington and H. Riley Spitler. 223 pages. Illustrated. Cloth bound. Price, $2.25.

☐ Book No. 6. *Transactions of the 10th Annual Meeting of the American Academy of Optometry*. Vol. VI. 1931. Published in 1932. Original papers and reports by Drs. Oscar L. McCulloch, L. H. Kraskin, George D. Oertel, O. J. Melvin, Chester H. Johnson, E. LeRoy Ryer, Elmer E. Hotaling, Ernest Petry, William Feinbloom, Edwin Forbes Tait, and John C. Neill. 114 pages. Illustrated. Cloth bound. Price, $1.25.

☐ Book No. 7. *Transactions of the 11th Annual Meeting of the American Academy of Optometry*. Vol. VII. 1932. Published in 1933. Original papers and reports by Drs. Walter I. Brown, J. Fred Andreae, E. LeRoy Ryer, Elmer E. Hotaling, Carel C. Koch, J. I. Kurtz, Richard M. Hall, A. H. Wittlig, Harry E. Pine, Don R. Paine, Lloyd K. Wyatt, Charles Sheard, H. Riley Spitler, William B. Needles, W. Jerome Heather, Robert N. Walker, Edwin Forbes Tait and William Feinbloom. 236 pages. Illustrated. Cloth bound. Price, $2.50.

☐ Book No. 9. *Transactions of the 13th and 14th Annual Meetings of the American Academy of Optometry*. Vol. IX. 1934 and 1935. Published in 1936. Original papers and reports by Drs. O. J. Melvin, J. Fred Andreae, Charles E. Jaeckle, Edwin Forbes Tait, John C. Neill, Howard C. Doane, Robert J. Beitel, William J. Tait, Julius Neumueller, J. I. Kurtz, Frederick W. Sinn, R. M. Hall, Robert N. Walker, William Feinbloom and Brant Clark. 240 pages. Illustrated. Cloth bound. Price, $2.50.

☐ Book No. 11. *Transactions of the 16th Annual Meeting of the American Academy of Optometry*. Vol. XI. 1937. Published in 1937. Original papers and reports by Drs. Richard M. Hall, J. Fred Andreae, Julius Neumueller, Robert J. Beitel, Nelson Greeman, William Henning, Don R. Paine, Lewis H. Kraskin, Glenn A. Fry, O. I. Crawford and William Smith. 109 pages. Illustrated. Cloth bound. Price, $1.25.

☐ Book No. 12. *Transactions of the 17th Annual Meeting of the American Academy of Optometry.* Vol. XII. 1938. Published in 1938. Original papers and reports by Drs. Richard M. Hall, J. Fred Andreae, Ida Feinbloom, Julius Neumueller, Harold M. Fisher, Robert J. Beitel, R. C. Baxter, Glenn A. Fry, Lewis H. Kraskin, Marvin J. Blaess and Marguerite Thoma Eberl. 126 pages. Illustrated. Cloth bound. Price, $1.25.

☐ Book No. 14. *Spatial Sense and Movements of the Eye.* Dr. Ewald Hering. Translated by Dr. Carl A. Radde. Published in 1942. 221 pages. Illustrated. Cloth bound. Price, $4.00.

We regret that Volumes II, III, IV, VIII, X, and XIII of *The Transactions of the American Academy of Optometry* are now out of print.

CAREL C. KOCH

BOOK REVIEWS

INTRODUCTION TO GEOMETRICAL AND PHYSICAL OPTICS by Joseph Morgan, Ph.D., Professor of Physics, Texas Christian University. McGraw-Hill Book Co. 1953. 450 pp. $6.50.

Designed to serve as a text for a four semester-hour course for physics students, this book is of more than passing interest to optometry students and teachers. A thorough, and at times quite condensed, account is given of the principles of geometrical optics, optical instruments, photometry, and physical optics. The book concludes with a chapter on spectra and one on wave-particle aspects of light and matter.

It is well illustrated and contains many problems numerical answers to some of which are given at the end of the book.

The author uses a cartesian sign convention, i.e., the type of sign convention used by Fincham, Emsley, and Southall. An interesting feature of the book is the manner of presenting the proofs of a large number of formulas. The page is divided into two columns, and a proof involving calculus is given on the right side and another one without the use of the calculus on the left side. Those whose mathematical education had included a thorough course in calculus will be happy to see that the proofs on the right side of the page are always more rigorous and complete and not infrequently shorter. There is little doubt that these two features, i.e., a cartesian sign convention and the optional use of the calculus, make the book a strong contender for adoption in optometry colleges.

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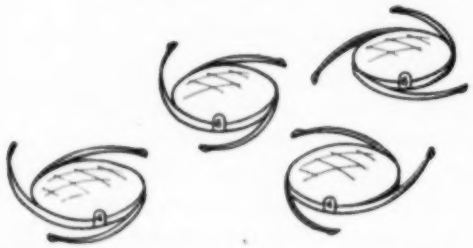

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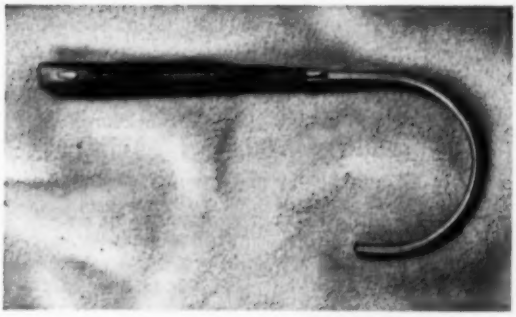

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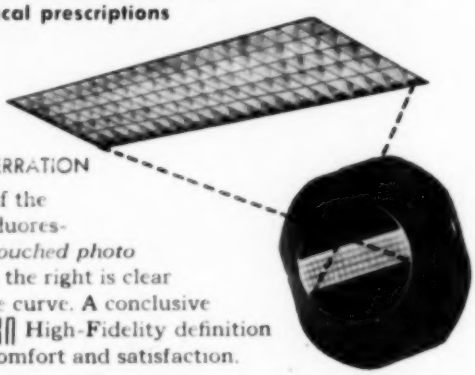

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The American Academy of Optometry has available a limited number of reprints of the following original papers. These monographs, printed with special board covers, will be mailed, postpaid, to professionally interested persons upon receipt of order, and the cost of reprint. Selection should be made by number. American Academy of Optometry, 1502 Foshay Tower, Minneapolis 2, Minn.

- ☐ Monograph No. 78. Readiness and Emotional Problems Associated with Reading Disabilities. Wilmot F. Schneider. 16 p. + cover. Price 35c.
- ☐ Monograph No. 79. Orthoptics Specification by a Graphical Method. Henry W. Hofstetter. 8 p. + cover. Price 25c.
- ☐ Monograph No. 80. Applications of Psychological Principles in Optometric Practice. Alfred Lit. 16 p. + cover. Price 35c.
- ☐ Monograph No. 82. An Objective High Speed Photographic Technique for Simultaneously Recording Changes in Accommodation and Convergence. Merrill J. Allen. 12 p. + cover. Price 30c.
- ☐ Monograph No. 83. Clinical Indications for Prescribing Prisms—With Three Case Reports. Rudolph T. Textor. 12 p. + cover. Price 30c.
- ☐ Monograph No. 84. A Comparison of Peripheral Stereoscopic and Visual Acuities. V. J. Ellerbrock. 8 p. + cover. Price 25c.
- ☐ Monograph No. 85. Balancing Visual Stimuli in Orthoptic Training. Matthew Luckiesh, R. M. Hall and S. K. Guth. 8 p. + cover. Price 25c.
- ☐ Monograph No. 86. Tonicity Induced by Fusional Movements. V. J. Ellerbrock. 16 p. + cover. Price 35c.
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- ☐ Monograph No. 88. Variations in Visual Acuity of a Group Without Major Refractive Errors. Newell C. Kephart and Joseph W. Wissel. 8 p. + cover. Price 25c.
- ☐ Monograph No. 89. Objective and Subjective Measures of Night Myopia. Z. J. B. Schoen. 8 p. + cover. Price 25c.
- ☐ Monograph No. 90. The Corneal Lens. Harold S. Harris. 24 p. + cover. Price 45c.
- ☐ Monograph No. 91. Combined Effects of Spherical Aberration and Diffraction on the Retinal Image. Glenn A. Fry. 12 p. + cover. Price 30c.
- ☐ Monograph No. 92. A Method for the Objective Measurement of Accommodation Speed of the Human Eye. Hermann Kirchhof. Translated by Henry A. Knoll and Merrill J. Allen. 16 p. + cover. Price 35c.
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- ☐ Monograph No. 94. Geriatrics and Optometry. Ralph E. Wick. 24 p. + cover. Price 45c.
- ☐ Monograph No. 95. The Clinical Aspects of Retrolental Fibroplasia with Report on One Case. I. Irving Vics. 8 p. + cover. Price 25c.
- ☐ Monograph No. 96. Further Investigation on the Pupillary Near Reflex. The Effect of Accommodation, Fusional Convergence and the Proximity Factor on Pupillary Diameter. Elwin Marg and Meredith W. Morgan, Jr. 12 p. + cover. Price 30c.
- ☐ Monograph No. 97. The Response of the Intra-Ocular Muscles of the Dog and Cat to Electrical Stimulation. Merrill J. Allen. 8 p. + cover. Price 25c.
- ☐ Monograph No. 98. Refractive Changes in the Eye over a Period of Years. William G. Walton, Jr. 20 p. + cover. Price 40c.
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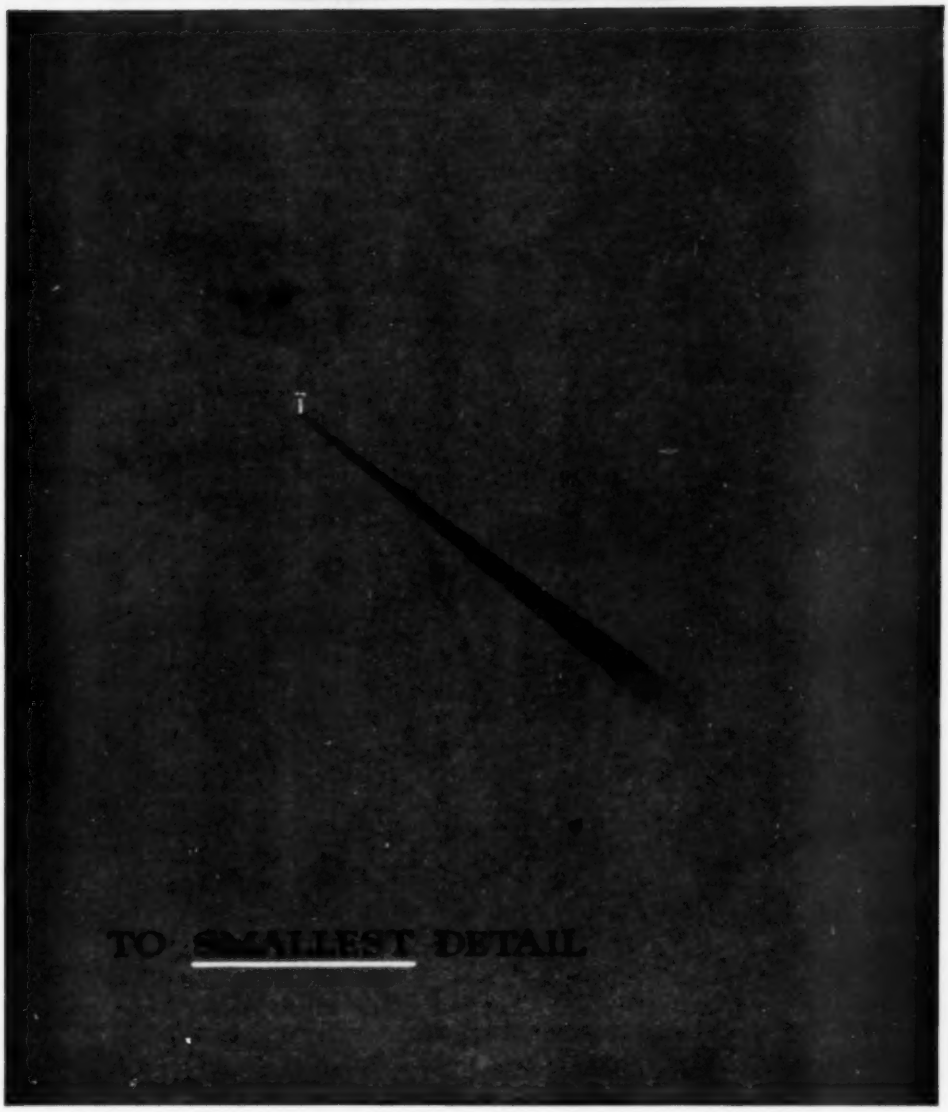

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